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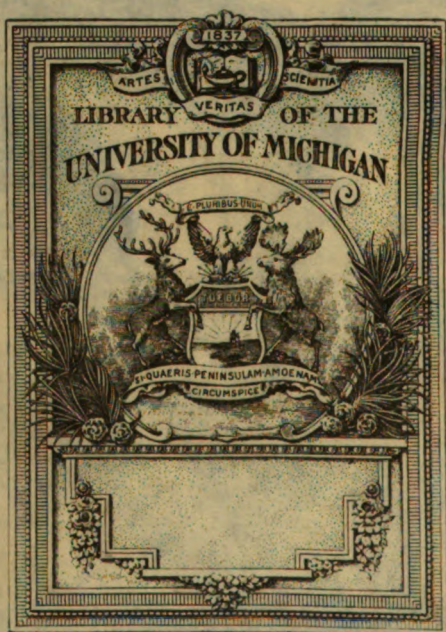
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# *Journal*

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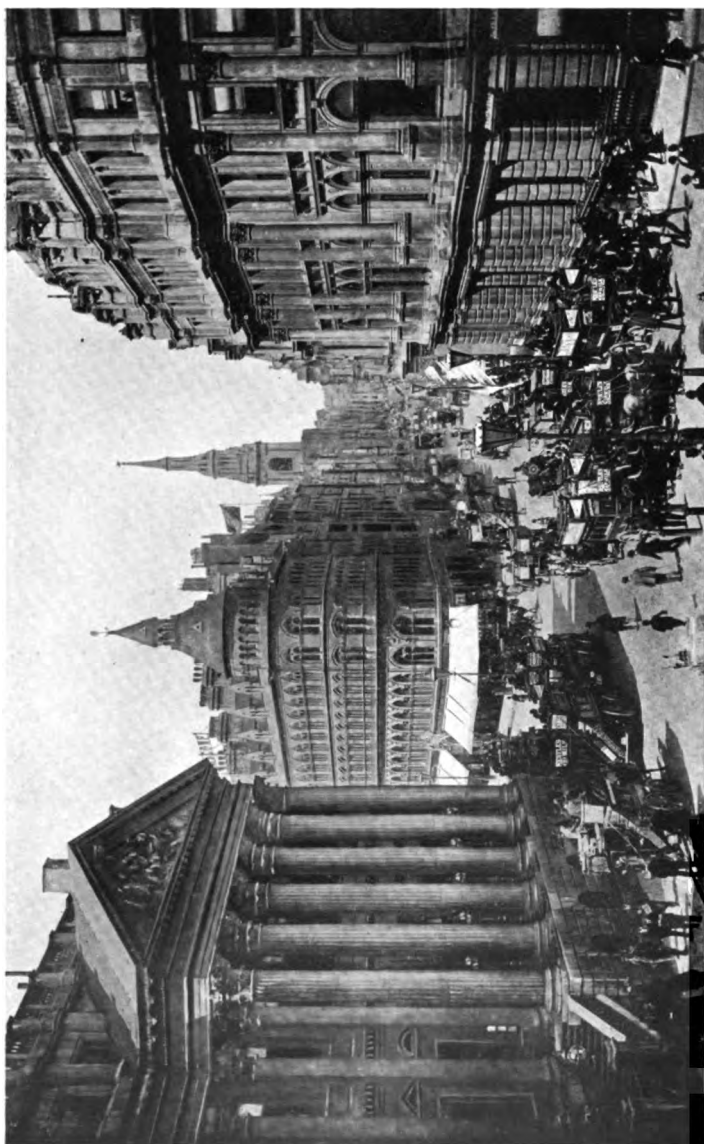












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# THE MANSION-HOUSE

# THE JOURNAL

OF THE

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VOL. LXXX.

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GEORGE C. LEVY,

SECRETARY.



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No. II

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## P R E F A C E.

**THIS** volume contains the proceedings of the Autumn Meeting of the Iron and Steel Institute, held in London in September 1909, together with the papers read and the discussion and correspondence thereon, and an illustrated account of the visits, excursions, and entertainments connected with the meeting.

The volume also contains a Report of the Congress of the International Testing Association, held at Copenhagen in the first week of September 1909. Obituary notices of deceased members, the library report, and the usual record of progress of the home and foreign iron and steel industries during the second half of 1909 occupy the remaining portion of the volume.

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# THE IRON AND STEEL INSTITUTE.

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## SECTION I.

### *MINUTES OF PROCEEDINGS.*

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#### LONDON MEETING.

THE AUTUMN MEETING of the IRON AND STEEL INSTITUTE was held at the Institution of Civil Engineers, Great George Street, Westminster, on Tuesday, Wednesday, and Thursday, September 28, 29, and 30, 1909, the Right Hon. the LORD AIREDALE OF GLEDHOW, Past-President, occupying the chair on the first day, Tuesday, September 28.

Lord AIREDALE, in opening the meeting, said he had to announce that the President, Sir Hugh Bell, had an important engagement in the north, and was unable to be present that day, but he would be present on the following day. He had asked him (Lord Airedale), and the Council had confirmed the invitation, to occupy the chair that morning. He had the advantage of being supported by the President-elect, His Grace the Duke of Devonshire, and with his assistance he thought he would have no difficulty in conducting the business. The Carnegie Gold Medal would be presented by the President on Wednesday.

The minutes of the last meeting were taken as read, and signed by the Chairman.

1909.—ii.

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The SECRETARY, in accordance with Bye-law 10, submitted the following list of Vice-Presidents who would retire by rotation at the Annual Meeting in May 1910: Mr. Arthur Keen, Sir W. T. Lewis, Bart., K.C.V.O., and Mr. P. C. Gilchrist, F.R.S. The following Members of Council would also retire by rotation: Mr. C. J. Bagley, Mr. J. H. Darby, Mr. W. Evans, Mr. J. E. Stead, F.R.S., and Sir Alfred Hickman, Bart. All these gentlemen are eligible for re-election, and it is competent for members to nominate candidates for office up to one month previous to the date of the Annual Meeting.

Mr. P. N. CUNNINGHAM (Glasgow) and Mr. O. A. MALMBERG (Harrow) were appointed Scrutineers, and, on the conclusion of their scrutiny, they announced that the following candidates had been duly elected members of the Institute :—

NAME.	ADDRESS.	PROPOSERS.
Andrews, Leonard, Assoc. M.Inst.C.E.	4 Queen Victoria Street, London, E.C.	E. G. Appleby, E. G. Sehmer, T. C. Hutchinson.
Audri, Alfred . . .	3 rue Laport, Liège, Belgium	Sir Hugh Bell, Bart., A. Greiner, G. Trassenster.
Antipin, Peter . . .	Nikolo Beresowka, Ufa, Russia	J. Petherick, E. G. Kirk- house, S. S. Horsfield.
Atkinson, Harald Milne	40 Brazenose Street, Manchester	Sir Hugh Bell, Bart., C. E. Stromeyer, A. E. L. Chorl- ton.
Ballereau, Nicolas .	Messrs. Schneider & Co., Le Creusot, France	Sir Hugh Bell, Bart., C. P. E. Schneider, E. Saladin.
Blackwell, Harold Alexandre	The Albany, Liverpool	F. Sutcliffe, W. J. P. Storey, G. Tate.
Bock, Patrik Hjalmar	Smedjebacken, Sweden	B. W. Head, R. Booth, Leslie S. Robertson.
Böcking, Dr. Alex- ander	10 Arthur Street, Red- car, Yorkshire	C. Ritter von Schwarz, A. Sonnenschein, Sir Hugh Bell, Bart.
Bondi, Max . . . .	Porto Vecchio di Piom- bino (Province di Pisa), Italy	C. Ritter von Schwarz, A. Sonnenschein, Sir Hugh Bell, Bart.
Bruce-Kingsmill, Major Julian, M.A., B.Sc., F.C.S.	4 St. Ann's Square, Man- chester	H. Bauerman, J. E. Stead, A. McWilliam.
Campbell, Professor William, Ph.D., D.Sc., M.A.	School of Mines, Colum- bia University, New York, U.S.A.	H. M. Howe, W. A. Bost- wick, J. E. Stead.
Cohade, Jean Joseph	Messrs. Schneider & Co., Le Creusot, France	Sir Hugh Bell, Bart., C. P. E. Schneider, E. Saladin.

NAME.	ADDRESS.	PROPOSERS.
Chamier, George, M.Inst.C.E.	Hankow, China	Z. T. K. Woo, C. Y. Wang, W. Kwong.
Coombe, Leslie Jackson	Abbeydale House, Beau- chief, Sheffield	H. P. Marsh, W. J. Armi- tage, W. R. Ellison.
Coulson, Richard Hed- ley Archer, Assoc.M.I.Mech.E.	Sir B. Samuelson & Co., Ltd., Middlesbrough	W. Hawdon, J. E. Stead, Iltyd Williams.
Danielsson, Alec Georg	Bofors, Sweden	C. Danielsson, B. W. Head, R. Booth.
Darley, Frederick .	142 Scott Road, Sheffield	H. Brearley, T. W. Willis, F. Best.
Davidsson, John . .	Hofors Iron and Steel Works, Hofors, Sweden	G. Jansson, P. Eriksson, G. Odelberg.
Dempster, Robert . .	Vale Royal Abbey, Hartford, Cheshire	J. Adamson, J. M. Gledhill, W. Dronsfield.
Divary, Edouard Edmond	Messrs. Schneider & Co., Le Creusot, France	Sir Hugh Bell, Bart., C. P. E. Schneider, E. Saladin.
Graham, Thomas Whitley	Mossbay, Workington, Cumberland	Sir John S. Randles, J. Lawrence Smith, R. E. Highton.
Griffith, George Ernest	3 Kenwood Bank, Shef- field	W. F. Osborn, T. Lambert, W. A. Walber.
Grönwall, Eugen Assar Alexis	Ludvika, Sweden	Professor T. Turner, E. G. Appleby, L. Yngström.
Harrison, William King	Hagley, near Stourbridge	A. E. Tucker, Col. James Patchett, F. W. Harbord.
Henshaw, Percy Black- burn	39 Glen Road, Sheffield	A. Gamble, P. W. Lee, G. E. Senior.
Humphries, Albert	220 Eglinton Road, Plumstead, Kent	J. M. Ledingham, R. J. Redding, P. B. Brown.
Husson, Camille . .	Messrs. Schneider & Co., Le Creusot, France	Sir Hugh Bell, Bart., C. P. E. Schneider, E. Saladin.
Jeans, Harold, Assoc. R.S.M.	165 Strand, London, W.C.	J. S. Jeans, G. Mure Ritchie, J. F. Melling.
Julliotte, Claude . .	Messrs. Schneider & Co., Le Creusot, France	Sir Hugh Bell, Bart., C. P. E. Schneider, E. Saladin.
King, Herbert Percy	24A Kiangse Road, P.O. Box 243, Shanghai, China	T. W. Willis, J. H. Jackson, R. Leffler.
Klein, Otto . . . .	Dahlbruch, near Siegen, Westphalia	J. H. Darby, Sir Hugh Bell, Bart., H. Spannagel.
Klein, Robert . . .	Dahlbruch, near Siegen, Westphalia	J. H. Darby, Sir Hugh Bell, Bart., H. Spannagel.
Koettgen, Carl . . .	Ceres, Sundridge Ave- nue, Bromley, Kent	J. H. Darby, A. Siemens, A. J. Capron.
Ley, Frank' . . . .	Neath House, Redcar .	B. Talbot, W. Crooke, Jun., F. P. Clarke.
M'Cosh, Andrew Kirk- wood	Messrs. Wm. Baird & Co., Ltd., Coatbridge N.B.	Sir Hugh Bell, Bart., Andrew Lamberton, Sir Robert A. Hadfield.
McCosh, William W.	Gartsherrie Iron Works, Coatbridge, N.B.	G. Ainsworth, E. P. Martin, A. Lamberton.
Merz, Charles Hester- man, M.Inst.C.E., M.I.E.E.	28 Victoria Street, Westminster, London, S.W.	Sir Hugh Bell, Bart., G. Ainsworth, W. Hawdon.



NAME.	ADDRESS.	PROPOSERS.
Moore, Ralph Switzer, M.E.	82 Victoria Street, London, S.W.	W. L. Johnson, Greville Jones, E. D. Morgan.
Perks, John . . .	Min-y-don, Tettenhall, Wolverhampton	Arthur Cooper, G. N. Adams, A. McBean.
Robinson, Philip Seymour	Railway Works, Rochdale	Wm. Dronsfield, W. F. Beardshaw, W. H. Dixon.
Robinson, Sydney Greenwood, M.I. Mech.E.	Palace Chambers, 9 Bridge Street, Westminster, London, S. W.	B. Blount, P. B. Brown, F. W. Harbord.
Routy, Marie Eugène, Auguste	Messrs. Schneider & Co., Le Creusot, France.	Sir Hugh Bell, Bart., C. P. E. Schneider, E. Saladin.
Siemens, Frederick .	10 Queen Anne's Gate, London, S.W., and Mittelstrasse 21, Berlin, Germany	Sir A. Hickman, Bart., E. Parkes, Professor T. Turner.
Slacke, Randal Beresford, M.I.E.E.	38 Deansgate, Manchester	E. G. Appleby, E. G. Selmer, T. C. Hutchinson.
Thompson, Robert .	155 Fenchurch Street, London, E.C.	S. J. P. Thearle, H. J. Cornish, F. L. Warren, C. Buchanan.
Thompson, William	155 Fenchurch Street, London, E.C.	S. J. P. Thearle, H. J. Cornish, F. L. Warren, C. Buchanan.
Tweddell, George Herbert	Edenholme, Beverley Gardens, Cullercoats.	W. Crooke, Jun., C. W. Fairweather, F. P. Clarke.
Walker, Robert Griffin	Myood, Wood Green, Wednesbury	Arthur Cooper, G. N. Adams, A. McBean.

Papers by Mr. E. J. Ljungberg (Falun, Sweden), Mr. C. A. Ablett (London), and by Professor H. F. Rugan (Tulane University, Louisiana, U.S.A.) and Professor H. C. H. Carpenter (Victoria University, Manchester) were then read and discussed, and the meeting was adjourned at 12 midday to the following morning.

The chair having been taken at 10.30 A.M. on Wednesday, September 29, by the President, Sir Hugh Bell, Bart., the following presentation was made:—

#### PRESENTATION OF THE ANDREW CARNEGIE GOLD MEDAL

The PRESIDENT said he had much pleasure in handing to Mr. A. M. Portevin the Carnegie Gold Medal for research. He would recall the fact that Mr. Portevin was educated at the Central School of Arts and Manufactures at Paris, and

had made a special study of the properties and characteristics of alloy steels. In the Carnegie Research Memoir submitted by him to the Institute, he gave results of further investigation of the properties of numerous special alloys with the object of ascertaining the influence of the elements added to steel. He (the President) felt sure that the Institute would regard it as being very desirable that work of that character should be recognised by the award of the Carnegie Gold Medal, which he now had much pleasure in presenting to Mr. Portevin.

Mr. A. M. PORTEVIN (Paris) having suitably acknowledged the presentation in French, papers by Mr. Greville Jones (Middlesbrough), Mr. R. S. Moore (London), Mr. F. J. R. Carulla (Derby), and Dr. J. Newton Friend (Darlington) were read and discussed, and the meeting was again adjourned at midday to the following morning, when

The PRESIDENT, having taken the chair at 10.30 A.M., on Thursday, September 30, papers by Mr. R. Price-Williams (London) and Mr. E. Adamson (Sheffield) were read and discussed, and a paper by Mr. Thomas Swinden (Sheffield), and a further paper by Dr. J. Newton Friend (Darlington), were taken as read.

#### VOTES OF THANKS.

Professor A. McWILLIAM (Sheffield University) said he was rather pleased that he had hitherto been one of the silent members at that meeting, because he had thus been able to reserve his energies and his voice for a very important honour that had been placed upon him. He rose to propose: "That the best thanks of the members be given to the Chairman, Sir Hugh Bell, Bart., and to the members of the London Reception Committee, for the generous hospitality they had extended to the members of the Institute, and for the excellence of the arrangements made for the convenience, instruction, and pleasure of the members during the present meeting." He did not think that resolution needed any words from him to support it; but as it was customary to add some words, he

supposed that he must not break through the rule. Those of them who had been connected with Reception Committees of that Institute knew how much work had to be done, and how much detail had to be gone into, in order that such a meeting might be a success. When they had the honour and pleasure of receiving members at Sheffield, and 1300 of them came down upon them, they went through that experience, and they knew how much it meant. He was sure that all the members must have enjoyed themselves very much. After all, he thought that if the Reception Committee could succeed in making the members enjoy themselves in London, it would have to be admitted that they had indeed succeeded, because he always thought it must be a difficult place in which to make people enjoy themselves. He had noticed on the night of Tuesday, when they had been taken to the theatre, the high esteem evinced by the Reception Committee for the visiting members, because they would not give them anything light or humorous, but something serious and solid, so that they could be quite solemn and reveal themselves to the London public as very grave persons indeed. With regard also to the previous night, he thought that the banquet was a magnificent success. Perhaps they did not always hear the truth in such speeches as that he was making, but he had, as a matter of fact, heard many remarks after the dinner was over, and he thought there was not a single member—although there were ladies there, and every one knew how critical they were—who did not say it had been a very splendid occasion, and that they had enjoyed themselves immensely. Perhaps the Scotch members might have been rather shocked at the singing of "The Land o' the Leal," but if so, that was the only point that could be mentioned. All the rest was splendid. He had very great pleasure in proposing the resolution he had put to them. From all the private remarks he had heard with regard to the meeting, there had not been a single member who had been dissatisfied with the way in which they had been received and treated.

Mr. RALPH SCOTT (Leeds) said that, as Professor McWilliam had gone so fully into all the details of the pleasures provided

for them, there was nothing left for him to say, but he had, nevertheless, very great pleasure in seconding the resolution, and in adding that he thought the Reception Committee had discharged its duties in a most efficient way. Those of them who had come from a long distance to London were exceedingly obliged for what had been done for them. He warmly seconded the resolution, which was then put and carried by acclamation.

The PRESIDENT, in acknowledging the vote of thanks, said that, on behalf of his colleagues and of the Reception Committee, he rose to return his very best thanks to the members for their kind vote. He would not deny that it was a somewhat difficult task to consider how to entertain in London "the potent, grave, and reverend signiors" who constituted the Iron and Steel Institute; nor was their task at all easy when they had to take into consideration not only the "signiors," but the "signoras" and the "signorinas." He was glad to believe that the Committee had satisfactorily mixed grave and gay, and if the only fault they had made was to place upon the programme a song which created some dissatisfaction among the Scottish members, he would remind them that they had sinned in company with a very great man who made a bitter mistake, it might be remembered, in the interpretation of the word "Leal," which signified something quite different in the Scottish language from what he had imagined it to mean. He would not refer further, in regard to Mr. Gladstone's utterance, than to allude to the fact that he did once make such a mistake. What he (the President) had to say, and he said it with all his heart, on his own behalf and on that of his colleagues of the Reception Committee, was that "The labour we delight in physics pain." With that he tendered them their very best thanks for the vote passed.

Mr. E. P. MARTIN, Past-President, said he had the honour to propose "that the best thanks of the members be given to His Grace the Archbishop of Canterbury and Mrs. Davidson, to the Admiralty, the Army Council, the Lord Mayor of London (the Right Hon. Sir George Wyatt Truscott) and the

Lady Mayoress, and to the Master and Wardens of the Worshipful Companies of Mercers, Ironmasters, and Armourers and Brasiers, the Executive Committee of the National Physical Laboratory, Dr. and Mrs. Glazebrook, the Master of the Mint, and the proprietors and managers of the various works, for their courtesy in receiving members." Judging from the large numbers who attended and partook of the hospitality of those various persons, he could only say that he felt they fully deserved their best thanks.

Mr. ILLTYD WILLIAMS, Member of Council, said he had very great pleasure in seconding the vote of thanks which Mr. Martin had proposed, which was then put and carried by acclamation.

The PRESIDENT, in concluding the business of the meeting, said he had to move what was now an annually recurrent vote of thanks—in that instance occurring twice in one year—namely, "That the best thanks of the President, Council, and Members of the Iron and Steel Institute be given to the President and Council and Secretary of the Institution of Civil Engineers for the use of their rooms, and for the facilities afforded at the present meeting." The Institute was under a very deep debt of gratitude to its kind hosts who most readily placed those rooms at their disposal when they required them.

The motion, having been seconded by Professor TURNER, was put to the meeting and carried unanimously, whereupon the proceedings then terminated.

## PRODUCTION OF IRON AND STEEL BY THE ELECTRIC SMELTING PROCESS.

BY E. J. LJUNGBERG (FALUN, SWEDEN).

ON the whole there is at present not much more to add to what has already been published concerning the melting of steel by the use of electric current. Many types of furnace have been evolved and constructed—the Héroult, Kjellin, Stassano, Girod, Röchling-Rodenhauser, and others. It is also well known that furnaces up to a capacity of 15 tons have been built for making special steel with good commercial results. For making steel of ordinary quality the electric method still seems to be too expensive, even where cheap water-power is available.

At Gysinge, one of the works belonging to the Stora Kopparbergs Bergslag, there is one Kjellin induction furnace with a capacity of 2 tons, but as this is working as a Talbot furnace, not more than about 1 ton at a time is tapped.

The continuous current used in this furnace represents about 200 kilowatts, and the output in 300 days amounts to about 1200 tons of ingots using 50 per cent. pig and 50 per cent. scrap. As no other pig iron is used except the famous Dannemora brand made by the firm, which, as every one knows, is extremely low in phosphorus and sulphur, the process can hardly be called a refining process. The product is a carbon steel of high quality, possessing some superiority over steel made by the ordinary melting processes, the quality which I would instance specially being that it is comparatively soft to work, either hot or cold, although high in carbon. It is a superior carbon tool steel. It may be of interest to state that the company makes about 15,000 tons of Dannemora charcoal pig iron annually, of which about one-third is exported and two-thirds are used at the works at Söderfors and Elfkarleö for the manufacture of Dannemora Wallon bar iron, open-hearth, and crucible steel.

In the electric furnace, as well as in the crucible plant, there are also produced, among different kinds of special steel, high speed self-hardening steel, tungsten steel, chromium steel, and nickel steel. Such steels can easily be made in electric furnaces when the necessary care is taken. When speaking of high quality steel, all steelmakers know that the utmost care in heating, hammering, rolling, and tempering is necessary if a good result is to be obtained.

For a country like Sweden, possessing practically no coal-mines but numerous waterfalls, the manufacture of iron and steel direct from ore by the agency of the electric current is of much more interest than the melting of pig and scrap to make steel. At the works at Domnarfvet extensive and costly trials have therefore been made in the direct reduction of ore during this and the past few years.

In these experiments two modifications of a furnace, constructed by Mr. Wallin in Berlin, and several modifications of a furnace, constructed by Messrs. Grönvall & Lindblad (the Electro Metal Company), Ludvika, have been tried. Of these it is needless to describe any except the latest form.

The accompanying drawing shows a furnace similar to a common blast-furnace; but with three electrodes fed by three-phase alternating current at about 40 volts, 60 cycles, and 9500 ampères, averaging 674 horse-power, instead of tuyeres. In this furnace, which has been running for 1903 hours, there have been produced 280 tons of iron, containing from 0·95 to 3·09 per cent. of carbon.

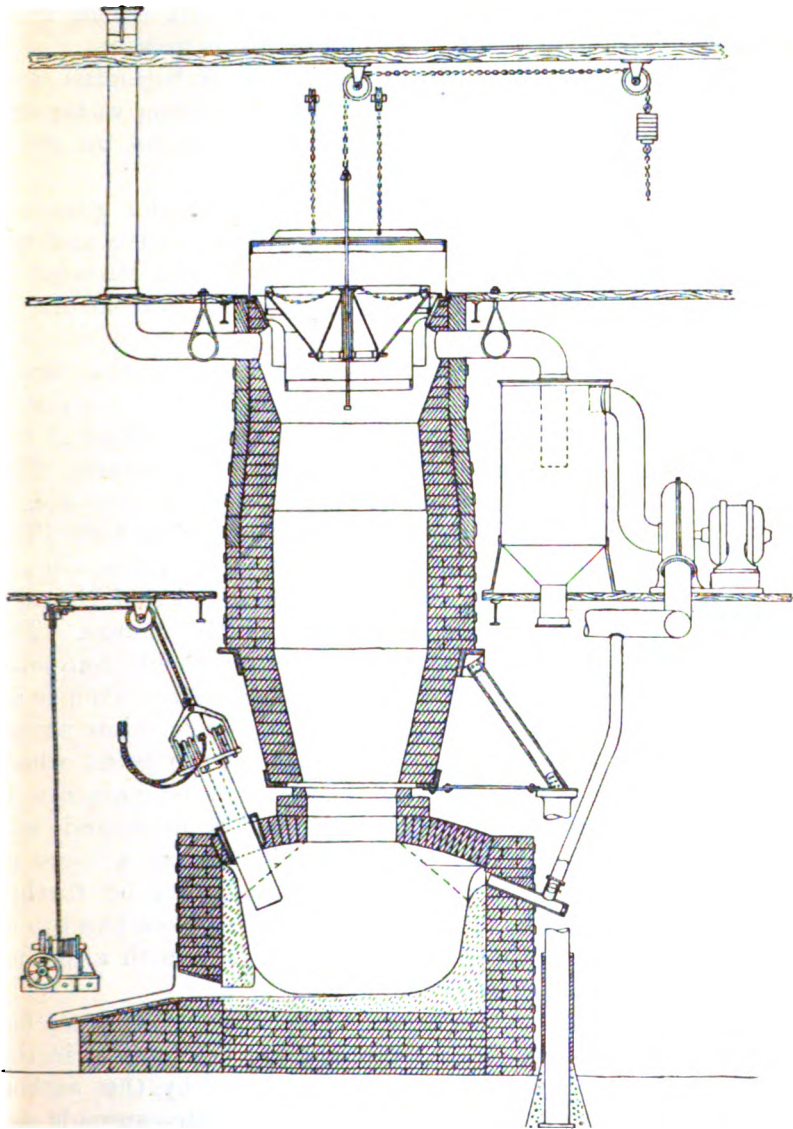
In the manufacture of this quantity there was used :—

	Tons.
Ore . . . . .	442
Lime . . . . .	24
Coke . . . . .	41
Charcoal . . . . .	58
Electrodes, total . . . . .	6·5
Electric current (kilowatt-hours) . . . . .	891,623

or per metric ton of pig iron produced :—

	Kilogrammes.
Coke and charcoal . . . . .	353·3
Power, horse-power year . . . . .	0·492
Electrodes, effective . . . . .	8·8 kgs.
Wasted ends . . . . .	13·9 "
	22·7
Pig iron from ore and lime . . . . .	60·02
Pig iron from ore alone . . . . .	63·50
Pig iron per horse-power year . . . . .	2·03 tons.

The temperature of the escaping gases from the furnace is



generally very low, and contain on an average about 22 per



cent. of carbon dioxide (from 8 to 41 per cent.). The amount of carbon monoxide varies from 39.4 per cent. to 61 per cent. The gases contain practically no nitrogen, but steam from the water in the ore, lime, coke, or charcoal is present.

The efficiency of the electric current ought to be higher than hitherto, if the considerable loss of heat by cooling water and radiation can be reduced. These losses seem to be about 30 per cent.

No air whatever is used in the process, and the gases are produced from the carbon in the charcoal and coke and the oxygen in the ores ( $\text{FeO} + \text{C} = \text{Fe} + \text{CO}$ ). Either charcoal or coke may be used, but the consumption of fuel will be practically the same in either case.

According to the description of the inventor, the figure shows a vertical section through the furnace, which consists of a lower portion or smelting chamber, corresponding to the hearth of a blast-furnace, and a top section or shaft. The latter is supported on columns, which prevent any weight from bearing on the arch of the smelting chamber. The latter is so proportioned as to provide a considerable amount of free space between the charge and the arched roof through which the carbon electrodes project into the charge. The brickwork is thus protected against any very high temperature, and remains a non-conductor of electricity. This is an important feature of this furnace, since experiment has shown that if the electrodes enter the chamber at the point where the charge touches the walls, a very high temperature is generated at this point; the brickwork is destroyed and becomes a conductor of electricity, giving rise to a more or less complete short-circuit. The brickwork may be further cooled by means of a blast of cool gas taken from the top of the furnace and blown in round the electrodes with a fan, no heat being lost by this proceeding.

The ore and fuel are crushed to a suitable size, and are fed into the top of the furnace through the bell hopper in the usual way, the ore being partially reduced by the carbon monoxide rising through the charge. The latter spreads out in the smelting chamber as shown, and the reduction is there completed. Since the electrodes project well into the charge,

*Results from Different Ores used.*

Run . . . . .	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 1-7.
Average horse-power . . . . .	582	585	653	745	800	812	808	674
Materials used—								
Ore (kilogrammes) . . . . .	82,600	57,400	95,900	59,900	62,300	62,385	21,400	441,885
Lime (kilogrammes) . . . . .	4,034	9,834	2,202	2,396	3,115	1,933	322	23,936
Ore and lime (kilogrammes) . . . . .	86,634	67,334	98,102	62,296	65,415	64,318	21,722	465,821
Coke (kilogrammes) . . . . .	18,672	5,446	9,746	5,906	1,564	...	...	41,384
Charcoal (kilogrammes) . . . . .	1,468	6,925	9,618	7,891	12,578	13,622	5,792	57,894
Coke and charcoal (kilogrammes) . . . . .	20,140	12,371	19,364	13,797	14,142	13,622	5,792	59,228
Electric energy (kilowatt hours) . . . . .	187,467	116,591	198,935	105,485	123,130	116,770	44,245	891,623
Pig produced (kilogrammes) . . . . .	51,425	35,385	63,874	42,660	37,940	34,728	15,300	280,307
Electrodes burnt (kilogrammes) . . . . .	560	915	90	300	305	240	...	2,410
Electrodes used (kilogrammes) . . . . .	3,780	2,160	710	540	540	674	...	8,404
Pig per 1000 kilogrammes—								
Coke (kilogrammes) . . . . .	363.9	153.9	152.3	136.1	41.2	...	...	147.6
Charcoal (kilogrammes) . . . . .	28.5	192.9	150.4	185.0	331.5	392.2	377.9	206.5
Total fluid (kilogrammes) . . . . .	392.4	346.8	302.7	321.1	372.7	392.2	377.9	354.1
Pure carbon (kilogrammes) . . . . .	331.0	275.0	252.0	254.0	284.0	294.0	283.0	280.3
Horse-power (year) . . . . .	0.565	0.511	0.483	0.383	0.503	0.517	0.448	0.492
Pig per horse-power year (ton) . . . . .	1.77	1.96	2.07	2.61	1.98	1.93	2.23	2.03
Electrodes burnt (kilogrammes) . . . . .	10.9	25.9	1.4	7.0	8.1	6.9	0.0	8.6
Electrodes used (kilogrammes) . . . . .	73.5	60.9	11.1	12.7	14.3	19.4	0.0	30.0
Time—								
Hours . . . . .	475.0	309.5	416.5	204.0	216.0	198.0	74.5	1903.5
Effective (per cent.) . . . . .	92.1	87.4	97.0	94.2	96.8	98.2	100.0	94.1
Standstill (per cent.) . . . . .	7.9	12.6	3.0	5.8	3.2	1.8	0.0	5.9
Pig—								
Ore (per cent.) . . . . .	62.25	61.60	66.65	71.20	60.90	55.70	71.40	63.50
Ore and lime . . . . .	59.35	52.50	65.20	68.45	58.00	54.00	70.30	60.02

the highest temperature occurs in the centre of the latter, and the brickwork is thus kept cool compared with the walls of an ordinary blast-furnace.

It will be seen from the figures given in the paper that a step has been taken in the direction of replacing a considerable part of the fuel used in making iron and steel by the electric current, and that the problem is technically solved. As regards its commercial value, it is too early to make any definite statement yet, but this will be readily understood by all iron and steel makers when they reflect how many years it has taken to bring the Bessemer, the open-hearth, and the basic processes to their present state of perfection.

The table on p. 13 shows results obtained on different ores used.

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### *DISCUSSION.*

Mr. P. R. COBB (London) said that although Mr. Ljungberg contended that there had been practically no advance in the commercial value of electric furnaces, he (Mr. Cobb) had had an interview the other day with one of the principal inventors who happened to be in Great Britain. That gentleman had just returned from Canada, where he had been able to arrange some very large contracts, involving the use of three of the largest sizes of his furnace, at Sault Ste. Marie, by one of the principal Canadian iron-producing companies. That company took a very favourable view of the prospects of the process, and they had backed their opinion by investing capital in the erection of three furnaces. The inventor expected those furnaces to be running some time towards the middle of next year, and then something more definite might be forthcoming respecting the commercial aspect of the matter.

Mr. LJUNGBERG, in reply, wrote expressing his pleasure at hearing that three of the largest sizes of electro-metallurgical furnaces were to be built at Sault Ste. Marie, as the more people there were at work in developing the electric process the sooner would it be perfected. At the same time he thought that if Mr. Cobb would study his paper again he would find that he (Mr. Ljungberg) stated that in his opinion it was as yet too early to say anything about the economical aspects of the matter.

On the motion of the CHAIRMAN, a hearty vote of thanks was accorded Mr. Ljungberg for his paper.

## THE DETERMINATION OF THE ECONOMY OF REVERSING ROLLING-MILLS.

BY C. A. ABLETT, B.SC., A.M.INST.C.E. (LONDON).

### PRELIMINARY CONSIDERATIONS.

SINCE the last autumn meeting of the Iron and Steel Institute, five steelworks have decided to adopt electrically driven reversing rolling-mills, making in all over twenty firms who have come to this decision, and twelve such plants are at work in different parts of the world, one at least being installed to replace an engine less than ten years old which was in good condition.

The reasons influencing this decision may be briefly summarised as follows:—

- (I.) Greater economy in fuel consumption.
- (II.) Larger output from plant.
- (III.) Reduced running costs, *i.e.* reduction in cost of repairs, attendance, oil, &c., the reduction in the cost of oil being very striking.
- (IV.) Greater convenience and reduction of management expenses due to centralisation of power supply.
- (V.) The great economy of the electrical plant is maintained throughout the life of the plant, and does not diminish as the parts wear.

The capital cost of an electrically driven reversing-mill is greater than that of a steam-driven mill driven by a plain two-cylinder engine, but in the last two years the experience gained in setting a number of such plants to work has enabled the capital cost to be very materially reduced.

Further reductions in the capital cost are scarcely possible unless some entirely new method of reversing-mill driving is evolved in place of the Ilgner system, which has been employed exclusively up to the present, and the present state of electrical knowledge does not offer much prospect of this.

In a very large number of cases the economies which could be effected by the adoption of electric driving are found to amply justify the increased capital expenditure. At the present time, the question of saving in fuel consumption appeals to most steelmakers as the chief inducement offered by electrical driving, as the possibilities in the direction of greater output are not fully recognised, there being as yet no published figures relating to this. It is therefore of interest to consider the methods by which the economy in fuel, power, or steam consumption can be ascertained.

Tests are frequently made to determine the economy of a reversing-mill engine, either—

- (I.) By indicating the engine and estimating the steam consumption per indicated horse-power from some of the larger diagrams, or
- (II.) Where boilers can be isolated, by measuring either the feed water or the coal burnt for a considerable period, and keeping a record of the tonnage of steel rolled over that period, so that the result is expressed in lbs. of coal or lbs. of steam per ton rolled.

In the author's opinion the results of such tests have little value for the following reasons:—

#### TESTS MADE BY INDICATING STEAM-ENGINE.

Where the steam consumption is estimated from indicator diagrams, it is common practice to consider only a few of the larger diagrams where the engine is working fairly economically. With a cogging-mill the ingot is seldom in the rolls for more than one-seventh of the total time taken to roll it down, and if a continuous set of diagrams be taken, it will be found that less than one-quarter of these represent anything like the full power of the engine.

The steam consumption corresponding to small diagrams is naturally considerably higher per indicated horse-power than that which corresponds to full load, so if the steam consumption was worked out for all the diagrams taken in rolling down an ingot, with a continuous indicator, the average steam

consumption per indicated horse-power would be shown to be much higher than if only a few of the larger diagrams were chosen.

Referring for a moment to the method of working out the steam consumption from indicator diagrams, it is usual to choose some point on the expansion line, and read the pressure at that point. As the total volume of steam in the cylinder is known from the distance the piston has swept through and the clearances, the total weight of steam in the cylinder can be obtained from the steam tables. Similarly, a point on the compression line can be chosen, and the total weight of steam remaining in the cylinder after the exhaust is closed can be calculated. The difference between these two quantities gives the weight of steam exhausted from the cylinder per stroke as obtained from the diagrams.

This value is less than the true steam consumption per stroke, as losses due to condensation, blowing past the piston, through the stuffing-boxes, &c., are not considered, and the figure obtained from the diagrams has to be multiplied by a constant to allow for this.

The constants for the various types of continuous running engines are fairly well known, as there have been ample opportunities for comparing the steam consumptions obtained from indicator cards with water measurements. With reversing-mill engines the selection of such a constant forms the weak point of this method, owing to the difficulty of obtaining reliable data to go on. It is quite obvious that the constant is greater for small diagrams than for large ones, as more condensation takes place, and the constant also depends on the cycle on which the engine has been working, for where the time taken by the passes is long compared with the interval between them, as in the case of a rail finishing-mill, the constant will be smaller than in the case of a cogging-mill, where the time taken by the passes is a comparatively small proportion of the total time, so that the cylinders have plenty of time to cool, and considerable condensation takes place. Similarly, whenever the mill is stopped, or has to wait between ingots, the cylinders cool, and increased condensation takes place.

It will be seen that in calculating the steam consumption from a set of continuous indicator diagrams, different constants should be employed, according both to the size of the diagrams and the way in which the engine is working, and so it is a very difficult matter to devise any means of making tests to check up the constants. A further disadvantage of determining the steam consumption from indicator diagrams is that no clue is furnished to the losses taking place before the steam comes to the engine stop-valve, such as blowing off from the boilers, and radiation, condensation, and leakage losses in the pipework. These are naturally higher in proportion to the total work done with a reversing-mill engine than with a continuous running engine, as the reversing engine is only giving full power for a small proportion of the total time it is working while the pipework is always full of steam.

The quantity of high-pressure steam which is exhausted at each reversal of the engine without doing any work, and which is clearly shown on the continuous indicator diagrams, is frequently not taken account of in determining the steam consumption.

#### TESTS MADE BY MEASURING FEED WATER OR FUEL BURNT.

The method of measuring the feed water or coal burnt per ton of steel rolled, which can only be carried out where it is possible to isolate boilers for the purpose, is open to the objection that two entirely different quantities are included in one measurement, *i.e.* the economy of the engine, and the actual work done in rolling the steel. This prevents any comparison being made between different engines, unless the same sections are being rolled from the same sized ingots under similar conditions in both cases.

Where it is possible to isolate the boilers supplying a reversing-mill engine, reliable figures for the steam or fuel consumption can be obtained by making a simultaneous test to determine the actual work required in foot-pounds to roll the ingots, supposing that the same sized ingots are being rolled down to the same section for a number of hours.

If a set of continuous indicator diagrams are taken during the total time that one ingot is being rolled, the combined area of the diagrams reduced to the proper scale, as determined by the steam pressure and the size of cylinders of the engine, gives the total work done on the ingot in foot-pounds. If this quantity be multiplied by the total number of ingots that were rolled while the test was taken and divided by 33,000 and by 60, the amount of work done by the engine during the test in indicated horse-power hours is obtained. If now the weight of coal burnt or feed water consumed be divided by the total horse-power hours as obtained above, the pounds of steam or pounds of coal per indicated horse-power hour is obtained, without incurring any of the sources of error mentioned above.

It is naturally desirable to take continuous diagrams for a number of ingots while the test is being made, and to take the mean of the results in order to avoid any chance of an error in the cards for one ingot. The author has usually found that when the total work done is obtained for a number of ingots, rolled under similar conditions, the values obtained agree within 5 per cent. In the case of a simple engine it is only found necessary to take continuous indicator diagrams at one end of one cylinder, which greatly simplifies such tests and lessens the labour of working up the results. The fact that the engine may make, say, five strokes during one pass while the indicator card shows only one stroke, is allowed for by calculating the total number of strokes made in all cylinders during the pass, from the length of the bloom and diameter of the rolls, and multiplying the average indicated work per stroke by the number of strokes. (See Plate I.) Experiments made to check this procedure have shown it to be very accurate.

In using this method of making tests it is naturally desirable to take some preliminary diagrams to check the valve-setting and to show if each end of each cylinder is doing its proper proportion of the work of the engine or not, and it will be found best to take these diagrams during the last passes when the bloom is long and the engine is giving diagrams approximately of the same size for a dozen strokes or more.



Where a compound engine is in use, continuous indicator cards should be taken simultaneously on one end of a high-pressure and one end of a low-pressure cylinder.

In what has been said above it will be seen that the diagrams are used to work out the total work done by the engine and not the power which it is giving, and that the steam consumption per indicated horse-power hour is deduced from the total work done in a given time. If the indicated horse-power was worked out for each indicator diagram the tests would become quite unnecessarily complicated, as it would be necessary to employ a tachograph to record the speed of the engine continuously and some apparatus to mark simultaneous points on the continuous indicator card and the tachograph record. A further complication would be introduced by the fact that the speed of a reversing-mill engine varies so rapidly that it changes considerably during the time taken to record one single diagram.

The above-mentioned tests do not furnish any clue to the mechanical efficiency of the engine, and in the author's opinion the usual method of arriving at this—*i.e.* taking indicator diagrams when the engine is driving the mill at full speed running light—shows the mechanical losses to be considerably less than they really are when ingots are being rolled, and that this is particularly the case when the engine is geared to the mill.

#### TESTS ON ELECTRICALLY DRIVEN MILLS.

The energy consumption of an electrically driven reversing rolling-mill as expressed in kilowatt hours (Board of Trade units) per ton rolled can be determined in the simplest possible manner by inserting an ordinary integrating wattmeter in the supply system, which is an instrument that can always be left in circuit and requires no attention. If a reading of this instrument before the commencement of a shift and a second reading at the end of the shift are taken, the difference gives the total kilowatt hours used during the shift, and dividing this by the tonnage rolled the total kilowatt hours per ton is obtained. Such readings can quite easily be taken for every

shift, and a continuous check on the energy consumption can be kept. Results expressed in kilowatt hours per ton are generally found most useful, as the cost of the kilowatt hour varies according to local conditions, and knowing this cost, the total cost of power can be arrived at directly. The efficiency of the electrical plant can also be checked in the simplest possible manner by placing a second integrating wattmeter in the armature circuit of the mill motor.

The records of this wattmeter will be less than those of the one placed in the supply circuit, the difference being the losses in the electrical plant. This does not take account of the efficiency of the mill-motor armature, but as this is of the order of 97 to 98 per cent. it can well be neglected. The following figures show some characteristic values for the kilowatt hours per ton rolled obtained from tests on reversing-mills :—

	Kilowatt Hours per Ton.
$4\frac{1}{2}'' \times 4\frac{1}{2}''$ billets from 2·5-ton ingots. Output, 53 tons per hour . . . . .	22·5
$6'' \times 6''$ blooms from 2·5-ton ingots. Output, 63 tons per hour . . . . .	17·5
$8'' \times 8''$ blooms from 2·5-ton ingots. Output, 80 tons per hour . . . . .	13·0
$12'' \times 9\frac{1}{2}''$ blooms from 7-ton ingots measuring $34\frac{1}{2}'' \times 25''$ . Output, 65 tons per hour . . . . .	11·2
$32'' \times 9''$ slabs from 6-ton ingots measuring $36'' \times 19\frac{1}{2}''$ . Output, 40 tons per hour . . . . .	4·3
$32'' \times 5''$ slabs from 6-ton ingots measuring $36'' \times 19\frac{1}{2}''$ . Output, 40 tons per hour . . . . .	5·8
Flange rails, 100 lbs. per yard, from 2-ton ingots. Output, 30 tons per hour . . . . .	48·0
Beams, 120 lbs. per yard, from 1·5-ton ingots . . . . .	36·0
Channels, 92 lbs. per yard, from 1·5-ton ingots . . . . .	37·0

*DISCUSSION.*

Mr. ANDREW LAMBERTON (Coatbridge), Member of Council, said he felt sure that nothing was further from the desire or purpose of the author of the paper than that it should give rise to any misconception. Having said that, he felt it right to express the fear that the statements made in the paper would give rise to misconception. The title of the paper was, "The Determination of the Economy of Reversing Rolling-Mills," and on the first page there was a statement made to the effect that five other steelworks had gone into the question of the electrification of their reversing rolling-mills, and in one case had thrown out a steam-engine although it was only ten years old. That seemed to claim superior economy for the electrically driven mill, and the author proceeded to enumerate and specify the advantages. The first claim was greater economy in fuel consumption; the second, larger output from plant; the third, reduced running costs, such as reduction in cost of repairs, attendance, and oil; the fourth, greater convenience and reduction of management expenses due to centralisation of power supply; and the fifth, that the greater economy of the electrical plant was maintained throughout the life of the plant. The title of the paper, taken along with those claims, would naturally cause it to be inferred that Mr. Ablett meant to prove that the electrical driving of reversing rolling-mills resulted in great economy, when compared with steam-driven mills. He had studied the paper very carefully, and had not been able to find a single figure given to substantiate those claims. On the last page they had a statement of the power in kilowatt hours, taken in rolling certain sections, but the members of the Institute would remember that last year, at Middlesbrough, Mr. Ablett read a similar paper and gave records of power, taken in kilowatt hours, for certain sections rolled in electrically driven reversing-mills. He (the speaker) took part in that discussion, and suggested to the author that it would have been more useful had he given the cost in pounds, shillings, and pence of the rolling of those sections. Stating it in kilowatt hours was academic, but giving it in pounds, shillings, and pence was commercial, and he told the author that he thought steelworks owners in Great Britain would probably attach more importance to the commercial aspect than to the academic. Mr. Ablett's reply was, that it was quite a simple matter to find what it cost to roll steel, per ton, in electrically driven mills, when they had the kilowatt hours. All that was necessary was to apply the cost of the unit, which, he said, would vary in different places, and in different countries, and this was all the reply given at the time. He was sorry to say that they were still no further forward. Mr. Greiner, Member of Council, also took part in the discussion, and he (Mr. Lamberton) wished to quote a sentence or two from what Mr. Greiner then said, which was as follows:—

"The important question of electrical driving of reversing-mills had been studied very thoroughly in Germany. About a dozen plants had

already been put down. Two of those plants had been in operation for about a year, but it remained to be seen if they proved to be economical. A comparison of the cost of rolling a ton ingot electrically, with that of rolling by steam, had led to the following conclusions: With coal at present prices—and in Germany coal was at higher prices than here—and an annual depreciation of 15 per cent. on cost of first establishment, the electrical reversing rolling was very nearly as cheap as steam rolling, when the electricity was produced by gas-engines working with the waste gases from blast-furnaces, and for which gas nothing was charged; but very much dearer when coal had to be burned to produce the gas which produced the electricity."

Mr. Greiner made that statement a year ago, and Mr. Ablett had not in any way refuted it in his present paper. He (the speaker) was afraid that Mr. Ablett could not substantiate the claims for the higher economy of electrically driven reversing-mills, which he had put forward, or he would have done so. The all-important question for steelworks owners was: "Could ingots be rolled into finished sections or plates at a lower cost, per ton rolled, by installing electrically driven reversing-mills, as compared with steam-driven mills?" and the present paper supplied no answer whatever to that question. The chief points in making such a comparison were (1) the capital outlay involved, (2) the depreciation on that capital, and (3) the cost of fuel used. All other charges might be taken as equal in both systems.

Going carefully into the figures proved that the total cost of an electrically driven reversing-mill complete, worked out at practically double the cost of the most modern and economical steam-driven plant of the same capacity. As regards the depreciation on capital outlay, authorities were agreed that it was at least 10 per cent. for electrical machinery, and that was proved by the fact that the premiums charged by insurance companies on those risks were double those charged for steam-driven machinery. Mr. Michael Longridge, chief engineer of the Manchester Steam Users' Insurance Co., showed, in his annual reports, that the breakdowns in electrical dynamos, motors, &c., were abnormally high, and justified the high premiums charged. That was testimony of the most practical and convincing kind. Depreciation on such plant required to be much greater than on steam plant, and he was surprised that the author of the paper should make the claim that electrically driven mills cost less in repair and upkeep, as the whole of the facts, gained from lengthened experience of electrical plant, proved the very reverse to be the case.

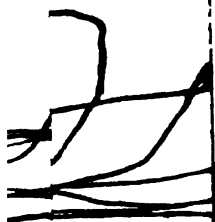
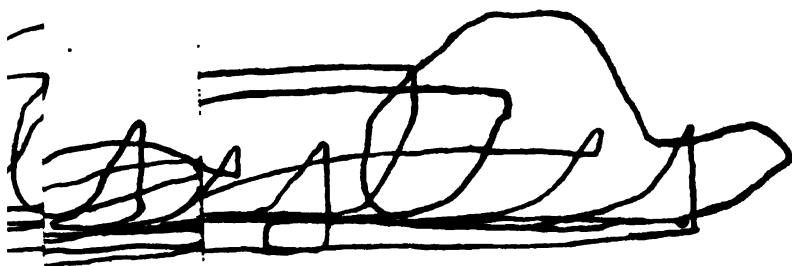
With regard to the cost of fuel: Mr. Greiner in his discussion on the paper of the previous year had further said that steam-driven plant could roll ingots into finished billets at the cost of 6d. per ton, which included 5 per cent. for interest on capital, 5 per cent. depreciation on plant, and the cost of fuel burned at the boilers, and that figure he (Mr. Lamberton) found to be substantially correct for high-class modern steam plants. Comparing that with the electrically driven reversing-mill, and taking 5 per cent. for interest on capital, and 10 per cent. depreciation on the electrical plant, the cost per ton of ingots rolled

worked out to 8s. 8d., even when getting gas from blast-furnaces for nothing. If the fair value of that gas were debited to the electrically driven plant, the comparison would be still more unfavourable. He put those figures forward in the hope that Mr. Ablett would deal with them, as it was of the greatest importance that the commercial aspect of the question be clearly determined. He wished further to draw attention to the paragraph in the paper where the author said: "Further reductions in the capital cost are scarcely possible unless some entirely new method of reversing-mill driving is evolved in place of the 'Ilgnér' system, which has been employed exclusively up to the present, and the present state of electrical knowledge does not offer much prospect of this." It was refreshing to find electricians admitting that there were some mechanical problems that they were unable to solve. Last year he (Mr. Lamberton) had indicated in a general way an idea which he was working out, having for its object the dispensing with the very costly "Ilgnér" apparatus referred to by Mr. Ablett. The accompanying diagram (Fig. 1) showed the arrangement he referred to. Most of the members were familiar with the ordinary clutch driven reversing-mills which had been successful in the past, but were subject to the objection of being excessively noisy, and destructive of the clutches. That was due to the fact that those clutches were put into gear when the mill was at rest and the engine at full speed, resulting in violent shock. If those clutches could be put into gear without shock, the objectionable features would be removed, and that he proposed to accomplish by using a friction clutch in the first instance, the function of which was to start the mill from rest and accelerate it to within 5 per cent. of the normal speed, when, automatically, the positive jaw clutch was put into gear and took the full load of rolling; and upon each reversal of the mill that process was automatically repeated by the movement of one controlling lever. The important point to notice in that device was, that the positive clutch was put into gear at practically coincident speed with that of the mill, and shock was in that way practically eliminated. He thought that those members who had had experience of the former clutch-reversing-mills, which went into gear at full speed when the mill was at rest, would appreciate the great advantage of gearing those clutches at coincident speed, and therefore practically without shock. The question might be asked: If he were going to use a friction clutch, why not use it alone, and make it powerful enough, not only to start the mill from rest, but to do the whole work of rolling?—but that had not been accomplished with any success, the excessive shocks of rolling being too much for friction clutches. With the combination of the positive jaw clutch to take the full loads of rolling, the friction clutch being entirely relieved of that shock, there seemed every prospect that such a gear would be successful, and he had referred to the matter in the hope that it would be of some interest to the members.

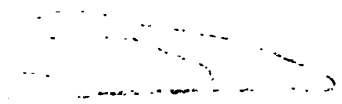
The CHAIRMAN said all present would know with what authority Mr. Lamberton spoke on that question. Mr. Lamberton gave the cost of rolling quantities continuously, day and night, with powerful rolling

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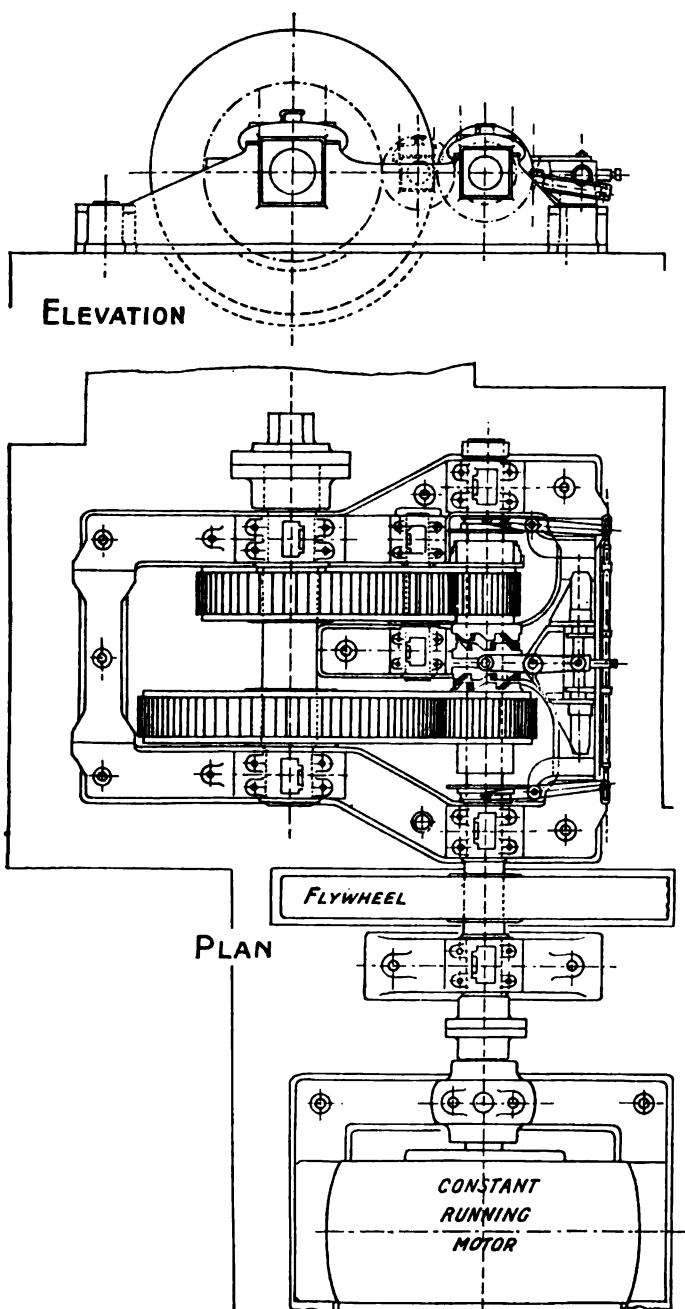


FIG. 1.



machinery. He (the Chairman) did not think that that absolutely disposed of Mr. Ablett, because he could imagine cases where there was no continuous rolling, and where it might be of very great advantage to use an intermittent power, such as electrical power which it was possible to draw from a general source. When there had been established throughout the country great stores of electrical energy it would become possible to obtain the quantity required on any particular occasion. In the case of steam power, in the instances which had been given, there had to be taken into consideration the installation of the boilers and the engines, and all the accessories which existed whether power was being used or not. In cases where it was possible to draw supplies of electricity from a general store, cessation of use was accompanied by cessation of payment for it. He (the Chairman) saw before him managers of rolling-mills working day and night producing enormous quantities, but he could imagine special circumstances where a high finish was required, and where it was desirable to work only one day turn. If they could draw their special supply of electricity during that period, they would not need plant installed which was unnecessary. It was a point he ventured to suggest in support of Mr. Ablett's possible defence.

Mr. ALEXANDER SIEMENS (London) remarked that the Chairman had already put part of the case to which he wished to draw their attention. Mr. Lamberton began by saying that the statement of the cost per kilowatt was absolutely academic and not practicable. The paper, however, distinctly called attention to the fact that that mode of giving the cost had been chosen because the kilowatt cost varied in different localities. Mr. Lamberton himself had drawn their attention to that fact by mentioning that sometimes an electrical plant could be driven by the waste gases from furnaces, so that the fuel cost nothing. At other times it had to consume its own coal, and cost a good deal more. Siemens Brothers had had more than twenty years' experience in their works, and they had sixteen hundred horse-power generating plant now. It was very easy to produce a kilowatt, including depreciation, repairs, and every possible charge that could be made, for a farthing per kilowatt hour. Therefore, if the figures on the last page of the paper were taken and divided by four, they would give the number of pence which it cost to roll a ton of steel. With regard to upkeep, a good many people did not realise that it was much cheaper to employ a big motor than a small motor. He had in mind a case in point. Some years ago a brewer had complained to him (Mr. Siemens) that he had installed an electric motor to drive a particular pump, that it always got hot, and was consuming no end of current, and that, indeed, it did not pay him at all. He (the speaker) told him to put in a motor which was twice the size. The brewer replied that that would take twice the current, but he said to him: "Do as I tell you, and see what will happen." The brewer afterwards came to him and said that the motor did not use half the current. He replied: "Certainly not; because if the motor is too small it will heat, and the heat will destroy the insulation, which will necessitate extensive repairs; and, besides, the current consumed in

heating the motor does not do work, and is there, therefore, absolutely wasted; whereas, in a big motor there is practically no heat waste, the current corresponding absolutely to the load." He (Mr. Siemens) had given a lecture on that point before the Royal Society of Arts, and had showed that the current in a motor depended only on the load, and not on the size of the motor. That lecture was delivered in 1881, but, although twenty-eight years had passed, many persons would appear not to have learnt the fact it conveyed yet. His firm had a central power-station in their works at Woolwich, and he hoped a good many of those present would visit those works that afternoon. He hoped to show them that the generating plant at Woolwich was in such condition as to work as well to-day as it worked twenty years ago, while the repairs to it had been practically nothing. That was simply because they had worked the generators and the motors within their power. That was the secret of avoiding repairs and reducing the cost of the maintenance of electrical plant. Whenever those present wished to apply motors, and somebody advised them to put in a 10 horse-power motor, he (Mr. Siemens) would advise them to put in a 15 horse-power motor, and they would not regret it. He thought that the figure of 15 per cent. for depreciation was certainly not justified when the plant was properly selected. Insurance companies had to live, and if they had got an excuse to charge a little more they would naturally charge it. With the exception of repeating that the pence per ton could be ascertained by dividing the figures given on the last page of the paper by four, he would leave to Mr. Ablett the further defence of the electrical plant. With regard to the clutch which Mr. Lamberton proposed to use, it looked very nice and worked beautifully on the diagram; but he had always been told that clutches, reversing clutches especially, in rolling-mills or in any mechanical parts which had to sustain such shocks as the clutch gear in a rolling-mill, would and must wear out. It was one of the very great advantages in the "Ilgnér" system that those shocks were taken up, not mechanically, but magnetically.

Mr. ABLETT, in reply, stated that he did not write the paper in order to prove the economy of the electrical system of reversing-mill driving, but to urge steelmakers to make such tests themselves as would show them the economy of that system, and the tests which he had already carried out on reversing-mills were sufficient to convince him that, in a large number of cases, the economy to be obtained was well worth the additional capital cost of the electrical plant.

About two weeks before the last autumn meeting of the Iron and Steel Institute, that was September 4, 1908, a large electrically driven reversing cogging-mill, dealing with a large output, had been put to work in the neighbourhood of Essen, that electrical equipment being installed to replace a reversing steam-engine less than ten years old. The reason that it had been decided to install the electrical equipment was that the steam-driven mill could not give sufficient output, and it was either a question of installing an electrical equipment in order to obtain a larger output, or putting down an entirely new steam-driven cogging-mill.

The electrical contractors were able to promise 30 per cent. more output, and that figure had been justified by the performance of the plant. That electrically driven mill had run continuously since September 4, 1908, without a stoppage, and the change-over had also been effected without involving any stoppage of the plant, as the mill was driven by steam until a Friday evening, and on Saturday morning was connected up to the electric motor and disconnected from the steam-engine. A trial run was made on the Saturday afternoon, and the set was put into beneficial operation on the following Monday morning, and had been running ever since. The electrical equipment had enabled that works to effect a saving of 1s. per ton on an output of 5000 tons per week, while the oil consumption had been reduced to one-fifth of the previous consumption. Those who were interested in the subject ought to investigate the working of that mill for themselves. Since that mill had been set to work, three other large steelworks in the neighbourhood had placed contracts for electrically driven reversing-mills, and that showed that those works must see every cause for satisfaction in the operation of the plant, and the economy which could be obtained by its use.

Regarding the question of depreciation which had been raised, the figure of 15 per cent. given by a speaker in the discussion was unquestionably far too high, but it was not possible to say exactly what the figure should be, as there had been no really large electrical machinery running for so long as fifteen or twenty years. In connection with the question of depreciation, the case of the large electric generators at Niagara Falls might be quoted. They were set to work about fourteen years ago, and after some of the machines had been running for ten years it was found necessary to rewind the armatures, owing to the insulation becoming impaired by oil thrown from the bearings. That was quite an accidental circumstance, and would not occur with bearings of modern design. The rewinding represented a comparatively small cost, and after that had been done there was no reason why the machines should not run for another ten years, and possibly a third period of ten years after having been rewound a second time. An electrically driven reversing rolling-mill, which was somewhat smaller than the plant mentioned above, had been running for over two years without a single stoppage, and the cost of repairs on that plant had been practically nil.

The CHAIRMAN, in proposing that a hearty vote of thanks be accorded the author for his paper, said the discussion had emphasised the importance of hearing both sides of a question, and that the facts contained in the paper were of great interest.

## THE "GROWTH" OF CAST IRONS AFTER REPEATED HEATINGS.

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Introduction—Mr. A. E. Outerbridge, jun.'s, previous work—Experiments to determine the conditions under which the maximum growth of cast iron takes place—Methods of measurement—Experiments with commercial cast irons—Experiments with iron-carbon alloys (white) (B to I)—Experiments with high-carbon medium-silicon alloys (grey and white) (J to L)—Experiments with white irons that became grey on heating (A and M)—Experiments with high-carbon ascending silicon alloys (grey) (N to S)—Increase in volume of alloys N to S on repeated heating—Increase in weight accompanying the growth of alloys N to S—Chemical changes during growth—Microscopic study of the alloys—Experiments with iron-silicon alloys (T to V)—The influence of gases on the growth of cast irons—Experiments with S—Experiments with N—Comparison with Mr. Outerbridge's results and conclusions—Summary—The agencies at work in the "growth" of grey cast irons on repeated heating—Recommendation as to cast iron; for annealing ovens.

### INTRODUCTION.

THE fact that certain types of cast iron "grow" after repeated heatings has long been familiar to engineers. Cast iron annealing ovens 8 feet in length, 3 feet in diameter, and  $1\frac{1}{2}$  inch in thickness, which are kept red hot for prolonged periods, sometimes "grow" to 9 feet in length in the course of use. Cast iron furnace grates, range fittings, &c., which are subject to alternate heating and cooling, are frequently distorted and sometimes broken from the same cause. The Baltimore fire is of particular interest in this connection, because what had previously been considered acceptable fire-proof construction was proved to be unsatisfactory owing to damage done to the

masonry by the "growth" of the cast iron members of the iron-work construction. Floor levels were destroyed, and walls which had in other respects withstood the action of the fire were found to be unsuited for further use owing to their having been forced out of the perpendicular from this cause.

The same fire also furnished an illustration of the fact that under the same treatment mild steel does not grow. In spite of the entire inflammable contents of a sixteen-storey building being burned, the steel framework remained "plumb and intact." Other instances of a similar kind have been recorded.

Further, it is well known that wrought iron contracts permanently after repeated heatings. Mr. Humphrey Wingfield, who drew the attention of one of the authors to these facts in a correspondence arising out of his paper entitled "Structural Changes in Nickel Wire at High Temperatures,"\* suggested that these might be related phenomena, and that it would be interesting to discover an alloy intermediate between cast iron on the one hand, and mild steel and wrought iron on the other, which neither expanded nor contracted after repeated heatings. This problem has been taken up by the authors, and the results of their investigations are recorded in the following paper.

#### PREVIOUS WORK BEARING ON THE INVESTIGATION.

Mr. A. E. Outerbridge, junr., of Philadelphia, has been the principal, indeed almost the sole, worker in this field, so far as the authors have been able to learn. His chief contribution to the subject is entitled "The Mobility of Molecules of Cast Iron,"† and the following is a summary of his results in so far as they affect the authors' problem.

\* *National Physical Laboratory: Collected Researches*, vol. iii. pp. 259-268. H. C. H. Carpenter.

† *Transactions of the American Institute of Mining Engineers*, 1905, vol. xxxv. pp. 223-244.

A cast iron bar,  $14\frac{1}{8}$  inches by 1 inch by 1 inch, was heated twenty-seven times to about  $800^{\circ}\text{C}.$ \* for one hour. In order to prevent scaling it was enclosed in an iron pipe, the ends of which were stoppered with clay. After this treatment it had increased in size to  $16\frac{1}{2}$  inches by  $1\frac{1}{8}$  inch by  $1\frac{1}{8}$  inch, corresponding to an expansion of 40.98 per cent. It is stated (p. 266) that "the enlarged bar weighed precisely the same as before treatment." The initial specific gravity was 7.13, the final 6.01. In a footnote to p. 231 it is recorded that this bar was given twelve additional heatings at  $800^{\circ}\text{C}.$ , after which its dimensions were 16.625 inches by 1.1406 inch by 1.1406 inch, corresponding to a total expansion of 46 per cent.; and that "the last six heatings made no appreciable increase in the size of the bar." Ultimate growth was thus reached in about thirty-three heats.

The chemical composition of this bar was not given. It is stated that "the only change in constituents was that a very small amount of combined carbon in this soft metal was converted into graphite by the annealing process. This increase of free carbon (the total amount of carbon remaining the same as before treatment) does not account in any way for the enlargement of the bar." Mr. Outerbridge further states: "The explanation which I offered at the time, and have since corroborated by very many tests, made under varying conditions, is that the crystals of cast iron, unlike those of steel or wrought iron, are capable of intermolecular movement within a wide range, the full extent of which I have not yet ascertained."

It was further found (p. 229) that "all grades of cast iron do not increase in cubic dimensions equally; soft iron, containing but little combined carbon, increases more rapidly than harder iron containing more combined carbon, while white iron in which nearly all of the carbon is in the combined form does not expand sufficiently to overcome the original shrinkage, even after all of the combined carbon has been changed to graphite, or rather to that form of free carbon known as 'Ledebur's Temper Carbon,' by this annealing process. Wrought iron and steel bars subjected to the same

\* Growth was noticeable at  $650^{\circ}\text{C}.$ , but was much slower.

repeated heating and cooling in a closed tube have all contracted slightly in cubic dimensions. The average contraction of such bars after about sixty heatings in a closed pipe is  $\frac{1}{8}$  inch per foot."

Mr. Outerbridge's summary of his experiments is as follows (p. 239): "All of the investigations so far made in expanding cast iron by heat, whether by pouring molten iron over cold bars, heating in a closed tube with or without charcoal, heating in a fire without any protection, or by direct radiation over a fire far removed from the flames, . . . produce practically the same results, and tend to convince me that the astonishing change in volume is a molecular, not a chemical, one; thus substantiating my original theory of the molecular mobility of cast iron.

"The peculiar property of cast iron of increasing in bulk under the influence of heat is inherent in the metal, and has existed for all time. It must therefore have been noticed to some extent long ago; but so far as I am aware, no careful study has ever been made of the phenomenon, if it was observed, and no previous knowledge has, I believe, existed of the fact that a bar of iron can be increased in bulk more than 40 per cent. over its original volume while in the solid condition and still retain its metallic properties."

Photomicrographs of the untreated and treated cast iron are given from which Mr. Outerbridge concluded that the particles of iron were pushed apart by heat and did not return to their original positions when cold, but that the arrangement of the crystals was similar in both specimens.

The authors have been in communication with Mr. Outerbridge, and understand that he still adheres to these views, and that he has not published any later experiments bearing on them. The above summary does not of course exhaust the complete experimental data obtained by him. His pioneering work contains many other important observations. But they believe it to be a fair summary of his investigations in so far as they bear on the problem in hand.

In another account of the same work published in the

*Journal of the Franklin Institute*, April 1904, Mr. Outerbridge puts forward the view that the pressure caused by the expansion of occluded gases in cast iron plays a prominent part in the growth observed, and that these gases ultimately escape through the pores of the metal which have been expanded, the intermolecular spaces becoming filled with air. This is the only hint of the mechanism of the growth contained in his publications. The obvious reply to this is that mild steel also contains a considerable quantity of gases, and that if they are the cause of growth in cast iron then mild steel should also grow for the same reason. Like all good pioneering work, Mr. Outerbridge's investigations raise more questions than they settle, and a study of his papers led the authors to undertake a very extensive series of experiments, which they believe will be found to throw light on the interesting facts observed by him, and to give a clearer idea of the cause or causes at work in the permanent growth of many types of cast iron. These scientific investigations have contributed materially to the solution of the practical problem—"Can a commercial cast iron be made which neither expands nor contracts after repeated heatings?"

#### EXPERIMENTS TO DETERMINE THE CONDITIONS UNDER WHICH THE MAXIMUM GROWTH OF CAST IRON TAKES PLACE.

A grey cast iron was selected for this purpose. Bars of known length were heated in an electrically warmed tube furnace at certain temperatures and for certain periods, the temperature being measured by a platinum-platinum-iridium thermo-junction and direct-reading portable pyrometer. Three bars were heated at a given temperature. One was removed after one hour, another after two hours, and the third after three or, in some cases, seventeen hours. When cold they were remeasured. The following table summarises the results obtained:—

1909.—ii.

c



TABLE I.

Heat No.	Temperature.	Bar No. 1.		Bar No. 2.		Bar No. 3.	
		Time.	Growth in Inches.	Time.	Growth in Inches.	Time.	Growth in Inches.
1	600° C.	1 hour	nil.	2 hours	nil.	3 hours	nil.
2	650° C.	"	nil.	"	0·0020	"	0·0050
3	675° C.	"	0·0156	"	0·0250	"	0·0300
4	700° C.	"	0·0234	"	0·0342	"	0·0312
5	730° C.	"	0·0312	"	0·0346	"	0·0352
6	760° C.	"	0·0313	"	0·0350	17 hours	0·0352
7	800° C.	"	0·0313	"	0·0350	"	0·0352
8	860° C.	"	0·0313	"	0·0350	"	0·0352
9	900° C.	"	0·0315	"	0·0352	"	0·0355

Under the conditions of the experiments no growth was observed at 600° C.\* A slight expansion was evident after two hours' heating at 650° C., which was notably increased after another hour's heating at that temperature. At 675° C. the rate of growth, for a given period, increased about eight times. At 700° and 730° there were also substantial increases. But maximum growth was virtually reached in three hours at the latter temperature. The same expansion was obtained at 730° as at 860° C. The figures also show that three hours is a sufficient period of heating, no further growth being observed after seventeen hours. A very slight increase in growth was caused at 900° C., but it is only just perceptible. As this temperature is doubtless reached, and perhaps to some extent exceeded, in some of the practical uses of cast iron annealing ovens, the authors selected it for their later experiments, and in order to ensure maximum growth for a given heat the period of heating chosen was four hours.

\* Although in their experiments the authors found no permanent expansion of cast iron after heating for three hours at 600° C., they are aware that, if the heating is sufficiently prolonged, a growth has been found to take place at much lower temperature; e.g. cast iron valves subjected to superheated steam at 366° C. increase in size permanently. The length of time required for this, however, is such as to suggest that the phenomena are different.

## METHODS OF MEASUREMENT.

These were next considered in detail, commercial cast irons being used for the purpose. The first measurements were made with bars on which two points at a known distance from one another had been marked, the distance between the points being measured as the heats progressed. This method, however, was soon found to be unsatisfactory. After a number of

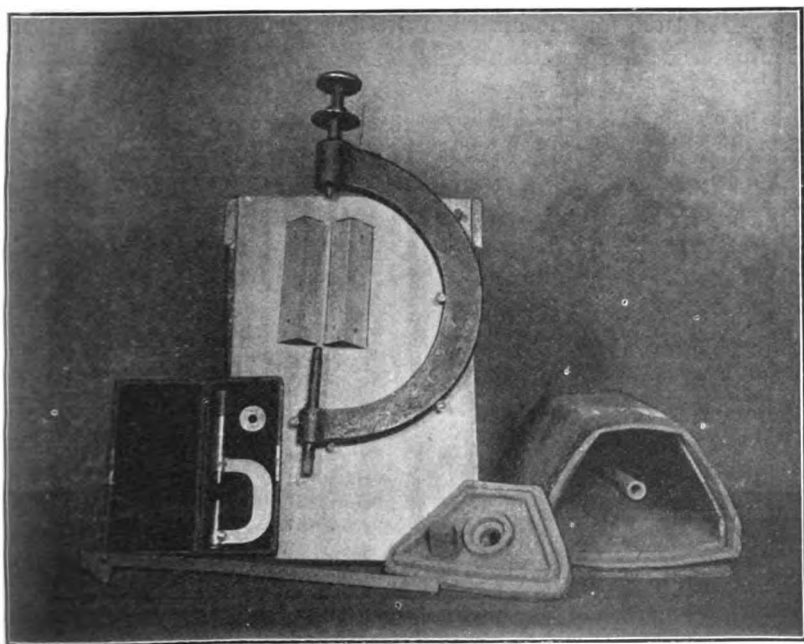


FIG. 1.—Illustrating the Micrometer Callipers used in Measurements, and the Cast Iron Muffle in which the Specimens were Heated.

heats at  $900^{\circ}$  C. a scale formed on the bars which rendered the marks indistinct and consequently the measurements uncertain.

It was decided to machine the bars accurately to a given length and diameter and to measure their expansion by micrometer callipers. The instruments used are shown in Fig. 1. The large callipers were of course used for length, and the small ones for diameter measurements, each recording

differences of 0.0001 of an inch. The figure also shows in the right-hand corner the retort in which the test-bars were heated. The retort was of grey cast iron and itself furnishes an illustration of the distortion of this material after repeated heatings, this particular retort having been heated upwards of fifty times to about 900° C. In its original form the bottom of the retort was flat. It was screwed on to a wrought-iron plate with a layer of asbestos in between to assist in the distribution of the heat inside the retort. In the centre was a cast-iron tube for the insertion of the thermo-junction used for temperature measurements.

The lid, also shown in the figure, was luted into the retort with clay in order to diminish air access. The packed retort was placed in a clay muffle, which was heated by gas externally in a large Fletcher furnace. The specimens were thus completely protected from the direct action of the flame. The authors' results nevertheless indicate that the products of combustion of the flame do enter the retorts and cause a scale to form on the specimens. It is, however, only after a considerable number of heatings that the accuracy of measurements is interfered with, as will be seen when the experiments come to be considered.

As a rule one heat per day was carried through. After the temperature in the retort had reached 850° to 900° C. it was maintained there for four hours. The bars always cooled at approximately the same rate, and they were not measured till next day, the greatest care being taken that they were then at the normal laboratory temperature.

#### SERIES OF EXPERIMENTS WITH COMMERCIAL CAST IRONS.

Three irons were selected.

The first was a mixture used by a firm for the manufacture of annealing ovens. The second was a mixture as far removed from the first in composition as they used. Bars of these were cast as follows: Four flasks were set up, two of green sand and two of dry sand construction, from each of which four bars were cast. The gate was in the centre, and the bars were fed from

the bottom, the top of the mould being open. Before pouring, the dry sand flasks were heated by bars of red-hot iron. One flask of each kind was poured from the same ladle, the only difference being that the bars cooled at a different rate. These bars are designated PH (hot), PC (cold), FH, and FC. The third sample was a bar cut from a new annealing oven obtained from another source, and is designated NIP.

These five samples were heated ninety-nine times for four hours at about  $850^{\circ}$  to  $950^{\circ}$  C. Detailed accounts of the measurements of length, diameter, and weight as the heats proceeded are given in Tables III. to VII. inclusive. The following summary, however, brings out the main features of the growths observed.

TABLE II.

Alloy.	Percentage.		Percentage Increase of Volume.				Percentage Increase of Weight after 99 Heats.
	Carbon.	Silicon.	After 10 Heats.	After 21 Heats.	After 52 Heats.	After 99 Heats.	
PC . . .	3.48	1.13	19.90	27.80	32.40	37.50	8.60
PH . . .	3.48	1.13	19.80	27.46	31.50	36.60*	8.50
FC . . .	3.41	0.95	8.71	18.25	26.55	35.21	7.86
FH . . .	3.41	0.95	13.05	22.45	28.10	35.70	7.82
NIP . . .	3.14	0.96	19.30	23.15	27.70	36.80	7.90

So far as carbon and silicon are concerned the compositions of the three alloys were not greatly different. Alloys PC, PH, and NIP grew rapidly and reached 50 per cent. of their ultimate growth after ten heats. After twenty-one heats their rate of growth became very slow. Alloys FC and FH grew more slowly at the outset, but ultimately nearly caught up the others. The rate of growth of PC and PH was very similar throughout, whereas FH, a more "open" iron than FC, grew more rapidly at the outset. In both series, however, the ultimate growth was nearly the same, irrespective of the initial rate of cooling of the alloy, varying from 35.21 to 37.50 per cent.†

\* Percentage growth after ninety-four heats.

† The volume of PH after ninety-four heats is introduced for purposes of comparison. After ninety-nine heats scale on the bar became detached and it was difficult to get an accurate measurement. The value for PH is thus slightly low, but not much.

TABLE III.—*Alloy PC. Cast in Green Sand.*

				Per Cent.		
Carbon . . . . .				3.48		
Silicon . . . . .				1.13		
Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Increase per Cent.	Weight. Grams.	Increase per Cent.	Heat No.
*5.996	0.7500	2.645	...	304.85	...	...
6.046	0.7563	2.710	2.47	...	...	1
6.071	0.7597	2.750	3.97	...	...	2
6.098	0.7638	2.790	5.50	...	...	3
6.121	0.7682	2.830	6.25	...	...	4
6.184	0.7726	2.880	8.90	...	...	5
6.212	0.7770	2.940	11.20	...	...	6
6.225	0.7793	2.960	11.95	309.71	1.60	7
6.266	0.7843	3.010	13.80	310.63	1.90	8
6.317	0.7881	3.080	16.50	311.96	2.34	9
6.384	0.7977	3.170	19.90	313.73	2.92	10
6.416	0.8024	3.250	23.00	315.86	3.63	11
6.444	0.8049	3.270	23.70	315.80	3.61	12
6.476	0.8090	3.320	25.60	316.94	3.97	13
6.499	0.8104	3.350	26.70	315.89	3.63	15
6.512	0.8113	3.360	27.05	315.57	3.52	17
6.522	0.8130	3.380	27.80	316.46	3.83	21
6.522	0.8126	3.370	27.50	315.56	3.52	22
6.528	0.8135	3.390	28.20	316.33	3.78	23
6.531	0.8136	3.395	28.40	316.42	3.79	24
6.531	0.8142	3.403	28.60	316.40	3.78	25
6.535	0.8142	3.410	29.00	316.80	3.92	26
6.532	0.8144	3.410	29.00	...	...	27
6.536	0.8150	3.420	29.35	316.93	3.97	28
6.539	0.8174	3.440	30.20	317.62	4.17	30
6.545	0.8165	3.430	29.70	317.76	4.22	32
6.554	0.8167	3.440	30.20	318.91	4.62	34
6.558	0.8170	3.445	30.30	319.03	4.65	38
6.582	0.8208	3.480	31.60	321.45	5.45	42
6.581	0.8207	3.460	30.85	320.73	5.23	47
6.595	0.8219	3.500	32.40	321.61	5.48	52
6.597	0.8220	3.505	32.50	321.36	5.42	57
6.609	0.8239	3.520	33.10	322.67	5.86	61
6.617	0.8235	3.525	33.40	323.12	6.00	71
6.638	0.8291	3.575	35.20	326.37	7.10	81
6.638	0.8269	3.560	34.70	325.03	6.60	84
6.664	0.8316	3.630	37.30	329.85	8.20	94
6.676	0.8337	3.635	37.50	331.00	8.60	99

\* Original.

TABLE IV.—*Alloy PH. Cast in Dry Sand Mould, Heated.*

Per Cent.

Carbon . . . . . 3.48

Silicon . . . . . 1.13

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Increase per Cent.	Weight. Grams.	Increase per Cent.	Heat No.
*5.9997	0.7496	2.647	...	305.87	...	..
6.0525	0.7567	2.720	2.76	...	...	1
6.0780	0.7600	2.750	3.90	...	...	2
6.1060	0.7646	2.800	5.80	...	...	3
6.1345	0.7685	2.840	7.30	...	...	4
6.1802	0.7734	2.900	9.60	...	...	5
6.1866	0.7783	2.940	11.10	...	...	6
6.2296	0.7790	2.960	11.90	310.94	1.66	7
6.2690	0.7838	3.020	14.10	311.87	1.96	8
6.3170	0.7840	3.060	15.30	313.36	2.45	9
6.3855	0.7860	3.170	19.80	314.68	2.89	10
6.4120	0.8008	3.230	22.10	315.62	3.20	11
6.4442	0.8038	3.270	23.50	316.70	3.55	12
6.4825	0.8085	3.320	25.50	316.63	3.52	13
6.5000	0.8110	3.350	26.70	316.74	3.58	15
6.5130	0.8110	3.351	26.75	316.79	3.60	17
6.5230	0.8125	3.370	27.40	317.49	3.80	21
6.5230	0.8120	3.365	27.20	316.44	3.47	22
6.5250	0.8128	3.380	27.70	317.04	3.66	23
6.5290	0.8138	3.390	28.10	317.29	3.75	24
6.5330	0.8138	3.400	28.50	317.36	3.77	25
6.5360	0.8139	3.410	28.80	317.78	3.90	26
6.5370	0.8140	3.415	29.00	...	...	27
6.5370	0.8144	3.416	29.20	317.80	3.92	28
6.5395	0.8147	3.420	29.30	318.49	4.15	30
6.5410	0.8150	3.425	29.50	318.39	4.10	32
6.5475	0.8156	3.430	29.65	319.49	4.45	34
6.5630	0.8165	3.435	29.75	320.47	4.79	38
6.5790	0.8185	3.450	30.40	321.75	5.21	42
6.5890	0.8204	3.465	31.00	322.08	5.32	47
6.5950	0.8210	3.480	31.50	322.60	5.49	52
6.6010	0.8212	3.490	31.90	322.62	5.50	57
6.6100	0.8227	3.520	33.00	323.58	5.80	61
6.6200	0.8231	3.540	33.80	324.70	6.17	71
6.6400	0.8263	3.570	34.70	327.34	7.20	81
6.6390	0.8263	3.560	34.40	325.86	6.56	84
6.6570	0.8319	3.620	36.60	330.54	8.01	94
6.6700	0.8397	3.700	†39.70	331.83	8.50	99

\* Original.

† This value is probably too high. Accuracy of measurement was rendered impossible owing to scale on the surface becoming detached.

TABLE V.—*Alloy FC. Cast in Green Sand.*

					Per Cent.	
					Carbon	3.41
					Silicon	0.95
Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Increase per Cent.	Weight. Grams.	Increase per Cent.	Heat No.
*5.9980	0.7506	2.654	...	307.48	...	...
6.0327	0.7549	2.700	1.73	...	...	1
6.0435	0.7566	2.720	2.48	...	...	2
6.0557	0.7578	2.725	2.67	...	...	3
6.0707	0.7594	2.750	3.62	...	...	4
6.0920	0.7624	2.780	4.75	...	...	5
6.1121	0.7638	2.800	5.50	...	...	6
6.1245	0.7654	2.820	6.25	309.23	0.57	7
6.1402	0.7667	2.830	6.65	309.57	0.68	8
6.1595	0.7687	2.850	7.40	309.99	0.82	9
6.1877	0.7713	2.885	8.71	310.40	0.95	10
6.2010	0.7732	2.910	9.65	310.87	1.10	11
6.2240	0.7757	2.940	10.75	311.54	1.32	12
6.2600	0.7795	2.970	11.90	312.10	1.50	13
6.3030	0.7838	3.045	14.70	313.43	1.93	15
6.3450	0.7872	3.080	16.00	314.11	2.16	17
6.3850	0.7920	3.140	18.25	315.83	2.72	21
6.3975	0.7944	3.160	19.05	315.87	2.74	22
6.4065	0.7953	3.190	20.20	316.33	2.87	23
6.4185	0.7970	3.200	20.55	316.41	2.91	24
6.4280	0.7976	3.205	20.75	316.36	2.90	25
6.4355	0.7976	3.210	20.90	316.50	2.94	26
6.4405	0.8006	3.245	22.25	...	...	27
6.4459	0.8016	3.255	22.65	316.59	2.96	28
6.4640	0.8022	3.260	22.85	316.88	3.06	30
6.4760	0.8028	3.270	23.20	316.65	2.98	32
6.4780	0.8029	3.272	23.25	316.62	2.98	34
6.4850	0.8011	3.270	23.20	314.96	2.44	38
6.5105	0.8045	3.305	24.50	317.13	3.15	42
6.5160	0.8063	3.330	25.40	317.13	3.15	47
6.5300	0.8106	3.360	26.55	318.68	3.65	52
6.5480	0.8117	3.380	27.35	319.39	3.88	57
6.5640	0.8171	3.440	29.60	320.34	4.20	61
6.5970	0.8184	3.455	30.30	324.14	5.40	71
6.6230	0.8230	3.540	33.60	326.62	6.24	81
6.6230	0.8219	3.520	32.80	325.76	5.95	84
6.6450	0.8280	3.580	35.20	330.16	7.37	94
6.6570	0.8290	3.585	35.21	331.61	7.86	99

\* Original.

† Sand fell out of hole.

TABLE VI.—*Alloy FH. Cast in Dry Sand Mould, Heated.*

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Increase per Cent.	Weight. Grams.	Per Cent.	
					Carbon	Silicon
					3.41	0.95
*5.9980	0.7507	2.654	...	307.27	...	...
6.0375	0.7563	2.700	1.73	...	...	1
6.0512	0.7578	2.720	2.49	...	...	2
6.0687	0.7604	2.750	3.63	...	...	3
6.0855	0.7630	2.770	4.37	...	...	4
6.1148	0.7630	2.810	5.89	...	...	5
6.1416	0.7710	2.860	7.79	...	...	6
6.1587	0.7720	2.880	8.52	310.15	0.93	7
6.1837	0.7744	2.900	9.29	310.64	1.10	8
6.2077	0.7768	2.940	10.80	311.32	1.32	9
6.2587	0.7830	3.000	13.05	312.44	1.68	10
6.2760	0.7860	3.030	14.20	312.93	1.84	11
6.3097	0.7892	3.080	16.05	314.24	2.26	12
6.3640	0.7950	3.150	18.05	314.86	2.47	13
6.3650	0.7988	3.180	19.80	315.55	2.68	15
6.4320	0.8010	3.245	22.30	315.97	2.82	17
6.4460	0.8030	3.250	22.45	316.52	3.00	21
6.4500	0.8038	3.265	23.00	316.11	2.87	22
6.4550	0.8040	3.270	23.20	316.67	3.05	23
6.4570	0.8047	3.275	23.40	316.41	2.97	24
6.4590	0.8041	3.265	23.00	316.01	2.84	25
6.4627	0.8050	3.280	23.60	316.33	2.94	26
6.4640	0.8053	3.290	23.90	...	...	27
6.4700	0.8061	3.300	24.35	315.92	2.82	28
6.4720	0.8064	3.302	24.50	316.49	3.00	30
6.4750	0.8067	3.305	24.60	316.11	2.87	32
6.4740	0.8072	3.310	24.70	316.65	3.05	34
6.4780	0.8066	3.310	24.70	†315.53	2.68	38
6.5010	0.8105	3.350	26.20	318.81	3.73	42
6.5155	0.8126	3.360	26.60	318.32	3.58	47
6.5300	0.8141	3.400	28.10	319.26	3.89	52
6.5390	0.8150	3.410	28.50	319.74	4.05	57
6.5580	0.8173	3.430	29.20	321.42	4.59	61
6.5840	0.8190	3.450	30.00	323.70	5.01	71
6.6140	0.8246	3.540	34.20	326.50	6.27	81
6.6140	0.8240	3.540	34.20	325.20	5.84	84
6.6350	0.8289	3.570	35.30	330.01	7.40	94
6.6460	0.8323	3.600	35.70	331.30	7.82	99

\* Original.

† Sand fell out of hole.



TABLE VII.—*Alloy NIP. Sand Casting.*

					Per Cent.	
					Carbon	3.14
					Silicon	0.965
Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Increase per Cent.	Weight. Grams.	Increase per Cent.	Heat No.
*5.9968	0.7500	2.648	...	305.70	...	...
6.0540	0.7570	2.725	2.91	...	...	1
6.0862	0.7620	2.775	4.80	...	...	2
6.1150	0.7660	2.820	6.50	...	...	3
6.1495	0.7722	2.870	8.39	...	...	4
6.1720	0.7789	2.940	11.01	...	...	5
6.2620	0.7743	3.010	13.70	...	...	6
6.2785	0.7862	3.040	14.80	311.51	1.91	7
6.3075	0.7894	3.110	17.40	312.01	2.07	8
6.3277	0.7915	3.120	17.80	312.56	2.25	9
6.3635	0.7957	3.160	19.30	312.75	2.31	10
6.3822	0.7976	3.180	20.10	313.24	2.47	11
6.4030	0.7993	3.210	21.20	313.53	2.56	12
6.4260	0.8010	3.230	22.00	313.90	2.69	13
6.4420	0.8022	3.250	22.70	312.69	2.29	15
6.4490	0.8023	3.255	22.90	312.79	2.32	17
6.4570	0.8039	3.260	23.15	313.40	2.52	21
6.4580	0.8040	3.275	23.65	312.81	2.33	22
6.4590	0.8046	3.280	23.90	313.18	2.45	23
6.4620	0.8048	3.285	24.10	313.40	2.52	24
6.4620	0.8050	3.285	24.10	313.01	2.49	25
6.4625	0.8050	3.285	24.10	313.41	2.53	26
6.4520	0.8044	3.270	23.45	...	...	27
6.4625	0.8050	3.285	24.10	313.02	2.40	28
6.4670	0.8058	3.290	24.30	313.68	2.62	30
6.4772	0.8064	3.300	24.65	313.82	2.66	32
6.4810	0.8065	3.305	24.80	314.64	2.93	34
6.4890	0.8056	3.300	24.65	313.73	2.64	38
6.5130	0.8097	3.350	26.50	316.91	3.68	42
6.5135	0.8108	3.360	26.75	316.16	3.44	47
6.5310	0.8125	3.380	27.70	316.93	3.70	52
6.5450	0.8136	3.390	28.01	317.22	3.77	57
6.5670	0.8173	3.435	29.70	319.18	4.42	61
6.5970	0.8230	3.500	32.25	321.46	5.16	71
6.6250	0.8275	3.550	35.40	324.89	6.29	81
6.6240	0.8273	3.540	34.90	323.35	5.80	84
6.6450	0.8314	3.610	36.20	328.50	7.46	94
6.6540	0.8340	3.625	36.80	329.79	7.90	99

\* Original.

Although the ends of the bars grew rather more rapidly than the sides, and numerous small cracks formed on the surface as the heats progressed, their ultimate shape was cylindrical.

An increase in the weight of the bars also took place, the rate being more uniform than in the case of the volume increase. The percentage increase after ninety-nine heats varied from 7·82 to 8·60.

Summarising the results of this series of experiments, it may be said that in their general features they are similar to those obtained by Mr. Outerbridge, with one important difference, viz. that whereas he states the weight of his enlarged bar was precisely the same as before treatment, the authors found a progressive increase in weight as growth proceeded. It is unnecessary at this stage to do more than note this difference. It will be discussed later (pp. 93-98).

Long before these experiments were concluded it had become clear that the first step to be taken in the elucidation of the cause or causes at work during the growth of cast iron by repeated heatings was to correlate "growth" with the composition of the material. This aspect of the investigation had been left untouched by Mr. Outerbridge. It was of course necessary to begin with simpler materials than the complicated cast irons of commerce, and the first series of alloys was designed so as to contain, as nearly as industrial processes permit, only iron and carbon. This series, and the remainder of the series of alloys mentioned in this investigation, were cast at the Openshaw Works of Sir W. G. Armstrong, Whitworth & Co.

### IRON-CARBON SERIES.

The compositions of the iron-carbon series are given in Table VIII.

The carbon descends broadly in half per cents. from 4 to the lowest carbon alloy that could be cast (0·15). The remaining constituents are present in sufficiently constant and, in the case of sulphur and phosphorus, small amounts. The rather higher figure for sulphur in alloy I was caused by the greater

time needed for melting. This series proved quite satisfactory for the purpose for which it was intended.

Each alloy was cast both in sand and chill moulds, the diameter of the bars being 1 inch. About 25 lbs. of each

TABLE VIII.

Alloy.	Percentage.				
	Carbon.	Silicon.	Manganese.	Sulphur.	Phosphorus.
A	4.03	0.243	0.15	0.018	0.010
B	3.70	0.233	0.16	0.018	0.011
C	3.08	0.172	0.13	0.019	0.010
D	2.59	0.146	0.12	0.016	0.012
E	1.96	0.215	0.20	0.013	0.015
F	1.58	0.168	0.17	0.015	0.014
G	0.99	0.233	0.19	0.015	0.012
H	0.55	0.182	0.20	0.013	0.014
I	0.15	0.186	0.15	0.040	0.017

were available. In no case was any graphite present; the alloys were exclusively white irons.

Machined bars of these alloys were subjected to as many as ninety heats in some cases. The chill castings were too hard for turning. Approximately a 6-inch length was ground in the lathe, the bar being held in a chuck while an emery-wheel was fed across the end surface. This gave a suitable form for length measurements. Near the centre of this bar a space of about 1 inch was ground to a true surface and served for diametric measurements. The remainder of the surface was left as cast.

These samples retained their shape throughout the heat treatment. In the case of alloy A the thickness of the scale after ninety heats was about 0.0015 inch. This tended to increase as the carbon of the series diminished.

The sand castings were less hard. They were turned to about 0.75 inch diameter in the form of 6-inch lengths. Alloys E, F, G, and H contained a number of blowholes.

The maximum temperature of the various heats was 960° C., the minimum 860° C.

Complete details of the volume and weight measurements

made from time to time are given in Tables XI. to XXVII. The volume measurements are in cubic inches, the weight in grams. Subjoined is a summary of the ultimate changes of volume and weight after the last heat. A plus quantity indicates an increase, and a minus quantity a decrease of volume or weight.

TABLE IX.—*Chill Cast Alloys.*

Alloy.	No. of Heats.	Percentage Change of Volume.	Percentage Change of Weight.
A	90	+6.880	-1.21
B	90	+0.238	-1.28
C	87	-0.840	-1.29
D	87	-0.822	-0.97
E	87	+1.140*	-0.75
F	48	+0.290*	-0.43
G	48	+1.350*	-0.12
H	48	+0.113*	-0.02
I	48	+0.800*	+0.03

TABLE X.—*Sand Cast Alloys.*

Alloy.	No. of Heats.	Percentage Change of Volume.	Percentage Change of Weight.
B	78	-0.350	-1.72
C	78	-1.675	-1.19
D	78	-0.915	-1.19
E	78	-0.026	-1.47
F	39	-0.405	-0.64
G	39	-0.470	-0.52
H	34	-0.507	-0.17
I	39	-0.060	+0.02

The sand cast alloys, which did not include A, not only did not grow under this treatment, but for the most part showed a progressive shrinkage. In the case of D, E, and I there was a momentary expansion as a result of the first heat or two heats, but it was followed by a contraction. In some cases the shrinkage reached a maximum value and then diminished somewhat. In others, as, for example, C, it progressed almost uninterruptedly through seventy-eight heats. In all cases the final result was a permanent shrinkage, which in six out of the eight alloys did not reach more than half 1 per cent.

\* These figures are high, on account of the scale which formed to a greater extent on the lower carbon members of the series. The same holds for the sand castings.

TABLE XI.—*Alloy A. Cast in Chill.*

						Per Cent.
Carbon . . . . .						4.03
Silicon . . . . .						0.243
Manganese . . . . .						0.15
Sulphur . . . . .						0.018
Phosphorus . . . . .						0.010
Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*5.9587	0.9486	4.2104	...	618.06	...	...
5.9440	0.9483	4.1976	-0.305	618.00	-0.01	1
5.9405	0.9490	4.2013	-0.216	617.82	-0.04	2
5.9427	0.9490	4.2027	-0.183	617.72	-0.05	3
5.9425	0.9487	4.1992	-0.266	617.57	-0.07	4
5.9400	0.9487	4.1977	-0.303	617.18	-0.12	7
5.9375	0.9477	4.1867	-0.562	617.00	-0.17	11
5.9420	0.9477	4.1902	-0.480	616.71	-0.22	13
5.9380	0.9480	4.1910	-0.460	616.55	-0.24	17
5.9360	0.9473	4.1831	-0.650	616.35	-0.27	18
5.9340	0.9472	4.1805	-0.710	616.34	-0.28	19
5.9360	0.9472	4.1825	-0.663	616.15	-0.31	20
5.9340	0.9474	4.1822	-0.670	616.00	-0.33	21
5.9340	0.9472	4.1810	-0.700	615.96	-0.34	22
5.9360	0.9475	4.1848	-0.609	...	...	23
5.9365	0.9470	4.1807	-0.710	615.59	-0.39	24
5.9355	0.9460	4.1711	-0.935	615.55	-0.40	26
5.9345	0.9467	4.1757	-0.826	615.22	-0.46	28
5.9400	0.9470	4.1835	-0.639	615.08	-0.48	30
5.9550	0.9470	4.1941	-0.358	614.44	-0.58	34
5.9660	0.9480	4.2108	+0.009	614.15	-0.63	38
5.9700	0.9482	4.2148	+0.105	614.24	-0.62	43
5.9780	0.9496	4.2330	+0.535	613.63	-0.71	48
5.9535	0.9509	4.2269	+0.392	612.62	-0.88	53
5.9645	0.9527	4.2500	+0.940	612.19	-0.95	57
6.0190	0.9594	4.3600	+3.550	611.17	-1.11	67
6.0770	0.9665	4.4500	+5.700	611.10	-1.12	77
6.0840	0.9665	4.4600	+5.940	610.29	-1.26	80
6.0870	0.9680	4.5000	+6.880	610.56	-1.21	90

\* Original.

TABLE XII.—*Alloy B. Cast in Chill.*

						Per Cent.
Carbon . . . . .						3.70
Silicon . . . . .						0.233
Manganese . . . . .						0.16
Sulphur . . . . .						0.018
Phosphorus . . . . .						0.011
Length. Inches.	Diameter. Inch.	Vclume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*6.0450	0.9406	4.1994	...	617.60	...	...
6.0395	0.9409	4.2000	+0.023	617.57	-0.00	1
6.0380	0.9414	4.2000	+0.023	617.42	-0.03	2
6.0380	0.9416	4.2000	+0.023	617.33	-0.04	3
6.0380	0.9411	4.1994	0	617.11	-0.08	4
6.0360	0.9400	4.1883	-0.263	616.43	-0.19	11
6.0360	0.9400	4.1883	-0.263	616.17	-0.23	13
6.0315	0.9400	4.1852	-0.335	616.02	-0.26	17
6.0350	0.9396	4.1850	-0.335	615.84	-0.28	18
6.0330	0.9399	4.1950	-0.095	615.83	-0.28	19
6.0280	0.9396	4.1792	-0.477	615.70	-0.31	20
6.0340	0.9398	4.1900	-0.224	615.55	-0.33	21
6.0240	0.9397	4.1900	-0.224	615.48	-0.34	22
6.0325	0.9398	4.1950	-0.095	...	...	23
6.0287	0.9391	4.1824	-0.406	615.14	-0.40	26
6.0260	0.9390	4.1600	-0.930	615.84	-0.45	28
6.0340	0.9394	4.1815	-0.430	614.71	-0.47	30
6.0340	0.9385	4.1737	-0.620	614.12	-0.56	34
6.0287	0.9385	4.1700	-0.690	613.67	-0.64	38
6.0335	0.9385	4.1733	-0.620	613.48	-0.67	43
6.0210	0.9397	4.1755	-0.571	612.49	-0.83	48
6.0170	0.9393	4.1691	-0.716	611.63	-0.96	53
6.0320	0.9390	4.1750	-0.571	611.18	-1.04	57
6.0380	0.9400	4.1900	-0.224	610.53	-1.15	67
6.0430	0.9418	4.2100	+0.238	610.62	-1.13	77
6.0550	0.9412	4.2200	+0.480	610.83	-1.10	80
6.0530	0.9373	4.2100	+0.238	609.71	-1.28	90

\* Original.

TABLE XIII. —Alloy C. Cast in Chill.

					Per Cent.	
	Carbon . . . . .				3.08	
	Silicon . . . . .				0.172	
	Manganese . . . . .				0.13	
	Sulphur . . . . .				0.019	
	Phosphorus . . . . .				0.010	
Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*5.6760	0.9513	4.0339	...	581.77	...	...
5.6700	0.9519	4.0350	+0.027	581.70	-0.01	1
5.6682	0.9512	4.0255	-0.208	581.56	-0.04	2
5.6690	0.9518	4.0340	+0.002	581.46	-0.05	3
5.6675	0.9515	4.0245	-0.109	581.33	-0.07	4
5.6700	0.9510	4.0300	-0.096	580.88	-0.15	11
5.6718	0.9508	4.0260	-0.198	580.62	-0.19	13
5.6718	0.9508	4.0260	-0.198	580.46	-0.22	17
5.6718	0.9508	4.0260	-0.198	580.27	-0.25	18
5.6718	0.9508	4.0260	-0.198	580.32	-0.25	19
5.6725	0.9508	4.0269	-0.174	580.17	-0.27	20
5.6718	0.9504	4.0255	-0.208	579.98	-0.30	21
5.6718	0.9504	4.0255	-0.208	579.93	-0.31	22
5.6718	0.9506	4.0272	-0.166	...	...	23
5.6718	0.9502	4.0238	-0.275	579.65	-0.36	24
5.6718	0.9498	4.0204	-0.335	579.63	-0.37	26
5.6718	0.9500	4.0221	-0.293	579.37	-0.41	28
5.6718	0.9503	4.0245	-0.234	579.25	-0.43	30
5.6718	0.9499	4.0212	-0.315	578.70	-0.53	34
5.6718	0.9506	4.0270	-0.175	578.41	-0.58	38
5.6582	0.9500	3.9900	-1.094	578.06	-0.64	43
5.6582	0.9504	4.0000	-0.840	577.36	-0.76	48
5.6582	0.9525	4.0200	-0.344	576.18	-0.96	53
5.6582	0.9512	4.0100	-0.592	575.60	-1.06	57
5.6446	0.9509	4.0000	-0.840	575.09	-1.15	67
5.6406	0.9512	4.0080	-0.822	575.14	-1.11	77
5.6250	0.9520	4.0000	-0.840	574.26	-1.29	87

\* Original.

TABLE XIV.—*Alloy D. Cast in Chill.*

	Per Cent.
Carbon . . . . .	2.59
Silicon . . . . .	0.146
Manganese . . . . .	0.12
Sulphur . . . . .	0.016
Phosphorus . . . . .	0.012

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*5.8380	0.9484	4.1239	...	601.38	...	...
5.8310	0.9486	4.1257	+0.046	601.32	-0.01	1
5.8302	0.9482	4.1159	-0.194	601.17	-0.03	2
5.8300	0.9485	4.1136	-0.250	601.10	-0.04	3
5.8282	0.9485	4.1176	-0.153	600.93	-0.07	4
5.8150	0.9485	4.1165	-0.169	600.48	-0.15	11
5.8120	0.9485	4.1171	-0.165	600.30	-0.18	13
5.8281	0.9485	4.1175	-0.155	600.21	-0.19	17
5.8281	0.9480	4.1135	-0.252	600.03	-0.22	18
5.8301	0.9484	4.1183	-0.136	600.09	-0.21	19
5.8359	0.9485	4.1122	-0.284	599.90	-0.24	20
5.8281	0.9482	4.1145	-0.228	599.80	-0.26	21
5.8281	0.9480	4.1135	-0.252	599.78	-0.27	22
5.8281	0.9483	4.1150	-0.216	...	...	23
5.8125	0.9481	4.1080	-0.507	599.54	-0.30	24
5.8125	0.9476	4.0989	-0.607	599.48	-0.31	26
5.8125	0.9487	4.1082	-0.380	599.34	-0.34	30
5.8125	0.9480	4.1025	-0.518	598.84	-0.42	34
5.8125	0.9490	4.1111	-0.310	598.70	-0.44	38
5.8125	0.9492	4.1128	-0.268	598.81	-0.43	43
5.8125	0.9499	4.1186	-0.128	598.99	-0.40	48
5.8125	0.9490	4.1111	-0.310	597.69	-0.61	53
5.8125	0.9497	4.1169	-0.170	596.90	-0.75	57
5.7812	0.9486	4.0855	-0.931	595.65	-0.95	67
5.7656	0.9501	4.0700	-1.305	596.09	-0.80	77
5.7500	0.9520	4.0900	-0.822	595.55	-0.97	87

\* Original.



TABLE XV.—*Alloy E. Cast in Chill.*

	Per Cent.
Carbon . . . . .	1·96
Silicon . . . . .	0·215
Manganese . . . . .	0·20
Sulphur . . . . .	0·013
Phosphorus . . . . .	0·015

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*5·9972	0·9655	4·3899	...	622·82	...	...
5·9962	0·9660	4·4000	+0·022	622·76	-0·01	1
5·9962	0·9656	4·3900	0	622·64	-0·03	2
5·9952	0·9664	4·4000	+0·022	622·56	-0·04	3
5·9965	0·9654	4·3882	-0·038	622·37	-0·07	4
5·9930	0·9653	4·3850	-0·110	621·91	-0·14	11
5·9897	0·9650	4·3800	-0·260	621·77	-0·17	13
5·9855	0·9652	4·3789	-0·251	621·68	-0·18	17
5·9875	0·9645	4·3750	-0·340	621·50	-0·21	18
5·9885	0·9650	4·3770	-0·295	621·55	-0·20	19
5·9887	0·9654	4·3825	-0·169	621·42	-0·22	20
5·9880	0·9650	4·3770	-0·295	621·31	-0·24	21
5·9870	0·9649	4·3760	-0·318	621·29	-0·24	22
5·9847	0·9648	4·3750	-0·340	...	...	23
5·9825	0·9647	4·3720	-0·408	621·09	-0·27	24
5·9832	0·9647	4·3725	-0·398	621·04	-0·28	26
5·9800	0·9649	4·3740	-0·364	620·85	-0·31	28
5·9777	0·9657	4·3775	-0·283	620·77	-0·33	30
5·9770	0·9653	4·3733	-0·379	620·44	-0·38	34
5·9700	0·9655	4·3700	-0·457	620·24	-0·41	38
5·9720	0·9671	4·3864	-0·080	620·40	-0·39	43
5·9670	0·9687	4·3970	+0·162	620·20	-0·42	48
5·9365	0·9688	4·3752	-0·336	617·94	-0·78	53
5·9395	0·9696	4·3800	-0·225	618·50	-0·69	57
5·9315	0·9700	4·3850	-0·091	617·90	-0·79	67
†5·9225	0·9713	4·4400	+1·140	618·07	-0·76	77
†5·9045	0·9763	4·4400	+1·140	618·16	-0·75	87

\* Original.

† Scaled.

TABLE XVI.—*Alloy F. Cast in Chill.*

	Per Cent.
Carbon . . . . .	1.58
Silicon . . . . .	0.168
Manganese . . . . .	0.17
Sulphur . . . . .	0.015
Phosphorus . . . . .	0.014

Length, Inches.	Diameter, Inch.	Volume, Cubic Inches.	Change per Cent.	Weight, Grams.	Change per Cent.	Heat No.
*5-9972	0.9655	4.3898	...	620.41	...	...
5-9972	0.9661	4.3958	+0.137	620.31	-0.01	1
5-9972	0.9656	4.3906	+0.016	620.17	-0.03	2
5-9950	0.9665	4.3973	+0.171	620.07	-0.05	3
5-9972	0.9656	4.3905	+0.016	619.99	-0.07	4
5-9920	0.9652	4.3837	-0.139	619.49	-0.14	11
5-9930	0.9651	4.3838	-0.137	619.37	-0.16	13
5-9890	0.9650	4.3782	-0.265	619.28	-0.18	17
5-9870	0.9650	4.3768	-0.296	619.16	-0.20	18
5-9865	0.9656	4.3833	-0.148	619.18	-0.20	19
5-9867	0.9658	4.3852	-0.105	619.05	-0.22	20
5-9847	0.9657	4.3825	-0.176	618.97	-0.23	21
5-9830	0.9655	4.3795	-0.235	618.95	-0.24	22
5-9825	0.9660	4.3839	-0.135	...	...	23
5-9810	0.9656	4.3792	-0.242	618.79	-0.26	24
5-9785	0.9659	4.3798	-0.228	618.74	-0.27	26
5-9770	0.9662	4.3817	-0.189	618.57	-0.29	28
5-9730	0.9669	4.3847	-0.116	618.49	-0.31	30
5-9690	0.9667	4.3800	-0.224	618.20	-0.35	34
5-9630	0.9670	4.3792	-0.242	618.14	-0.36	38
†5-9600	0.9687	4.3925	+0.061	618.40	-0.32	43
†5-9440	0.9710	4.4025	+0.290	617.75	-0.43	48

\* Original.

† Scaled.

TABLE XVII.—*Alloy G. Cast in Chill.*

	Per Cent.
Carbon . . . . .	0.99
Silicon . . . . .	0.233
Manganese . . . . .	0.19
Sulphur . . . . .	0.015
Phosphorus . . . . .	0.012

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*5.9902	0.9683	4.4105	...	621.02	...	...
5.9895	0.9693	4.4196	+0.206	620.98	-0.01	1
5.9905	0.9687	4.4144	+0.088	620.87	-0.02	2
5.9892	0.9689	4.4158	+0.120	620.81	-0.03	3
5.9890	0.9686	4.4126	+0.047	620.69	-0.05	4
5.9805	0.9692	4.4118	+0.020	620.45	-0.09	11
5.9805	0.9694	4.4136	+0.070	620.35	-0.10	13
5.9765	0.9696	4.4124	+0.043	620.31	-0.11	17
5.9760	0.9695	4.4114	+0.020	620.21	-0.13	18
5.9740	0.9695	4.4100	-0.010	620.25	-0.12	19
5.9725	0.9695	4.4089	-0.036	620.16	-0.14	20
5.9717	0.9699	4.4118	+0.029	620.05	-0.15	21
5.9707	0.9702	4.4135	+0.068	620.04	-0.16	22
5.9690	0.9707	4.4270	+0.374	...	...	23
5.9670	0.9706	4.4149	+0.100	619.93	-0.17	24
5.9647	0.9707	4.4233	+0.290	619.93	-0.17	26
5.9600	0.9713	4.4157	+0.116	619.81	-0.19	28
5.9580	0.9722	4.4226	+0.275	619.78	-0.20	30
5.9487	0.9728	4.4210	+0.240	619.59	-0.23	34
5.9370	0.9735	4.4189	+0.191	619.56	-0.23	38
†5.9345	0.9767	4.4460	+0.805	619.88	-0.18	43
†5.9180	0.9807	4.4698	+1.350	620.25	-0.12	48

\* Original.

† Scaled.

TABLE XVIII.—Alloy H. Cast in Chill.

	Per Cent.
Carbon . . . . .	0.55
Silicon . . . . .	0.182
Manganese . . . . .	0.20
Sulphur . . . . .	0.013
Phosphorus . . . . .	0.014

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*5.9952	0.9703	4.435	...	629.005	...	...
5.9957	0.9707	4.438	+0.068	628.95	-0.01	1
5.9955	0.9704	4.436	+0.022	628.88	-0.02	2
5.9945	0.9709	4.440	+0.113	628.87	-0.02	3
5.9950	0.9707	4.438	+0.068	628.84	-0.02	4
5.9935	0.9707	4.437	+0.056	628.78	-0.03	11
5.9917	0.9703	4.430	-0.113	628.75	-0.04	13
5.9895	0.9705	4.420	-0.340	628.73	-0.04	17
5.9890	0.9705	4.420	-0.340	628.63	-0.05	18
5.9875	0.9705	4.419	-0.363	628.69	-0.05	19
5.9875	0.9705	4.419	-0.363	628.60	-0.06	20
5.9860	0.9712	4.430	-0.113	628.54	-0.07	21
5.9845	0.9707	4.429	-0.135	628.51	-0.08	22
5.9840	0.9708	4.428	-0.162	...	...	23
5.9837	0.9708	4.428	-0.162	628.41	-0.09	24
5.9820	0.9707	4.427	-0.128	628.47	-0.08	26
5.9790	0.9713	4.440	+0.113	628.38	-0.09	28
5.9785	0.9717	4.445	+0.226	628.37	-0.10	30
5.9720	0.9717	4.440	+0.113	628.27	-0.11	34
5.9667	0.9724	4.425	-0.226	628.28	-0.11	38
5.9640	0.9731	4.430	-0.113	628.40	-0.11	43
†5.9590	0.9765	4.440	+0.113	628.88	-0.02	48

\* Original.

† Scaled.

TABLE XIX.—*Alloy I. Cast in Chill.*

	Per Cent.
Carbon . . . . .	0.15
Silicon . . . . .	0.186
Manganese . . . . .	0.15
Sulphur . . . . .	0.040
Phosphorus . . . . .	0.017

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*5.9942	0.9665	4.397	...	620.32	...	...
5.9947	0.9672	4.403	+0.137	620.28	-0.01	1
5.9955	0.9667	4.399	+0.045	620.24	-0.01	2
5.9945	0.9674	4.417	+0.456	620.24	-0.01	3
5.9950	0.9668	4.400	+0.068	620.23	-0.01	4
5.9940	0.9670	4.401	+0.091	620.25	-0.01	11
5.9962	0.9677	4.409	+0.274	620.26	-0.01	13
5.9950	0.9667	4.408	+0.267	620.28	-0.01	17
5.9950	0.9663	4.406	+0.206	620.21	-0.02	18
5.9945	0.9668	4.399	+0.045	620.24	-0.01	19
5.9920	0.9668	4.387	-0.228	620.20	-0.02	20
5.9930	0.9667	4.407	+0.228	620.11	-0.03	21
5.9930	0.9665	4.406	+0.206	620.12	-0.03	22
5.9930	0.9669	4.399	+0.045	...	...	23
5.9927	0.9667	4.397	0	620.13	-0.03	24
5.9910	0.9665	4.394	-0.068	620.11	-0.03	26
5.9900	0.9669	4.397	0	620.06	-0.04	28
5.9895	0.9669	4.390	-0.160	620.07	-0.04	30
5.9870	0.9670	4.396	-0.022	620.04	-0.04	34
5.9850	0.9671	4.395	-0.045	620.18	-0.02	38
†5.9860	0.9679	4.404	+0.160	620.45	+0.02	43
†5.9870	0.9709	4.434	+0.800	621.50	+0.03	48

\* Original.

† Scaled.

TABLE XX.—*Alloy B. Cast in Sand.*

	Per Cent.
Carbon . . . . .	3.70
Silicon . . . . .	0.283
Manganese . . . . .	0.16
Sulphur . . . . .	0.018
Phosphorus . . . . .	0.011

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*6.0330	0.7538	2.6925	...	338.41	...	...
6.0300	0.7531	2.6857	-0.252	338.10	-0.09	2
6.0280	0.7539	2.6908	-0.063	337.95	-0.13	4
6.0240	0.7540	2.6897	-0.104	337.74	-0.20	8
6.0230	0.7527	2.6802	-0.860	337.70	-0.21	9
6.0230	0.7534	2.6850	-0.280	...	...	10
6.0235	0.7537	2.6868	-0.212	337.24	-0.34	11
6.0250	0.7533	2.6853	-0.268	337.19	-0.36	12
6.0190	0.7530	2.6802	-0.860	336.96	-0.43	13
6.0180	0.7535	2.6834	-0.338	...	...	14
6.0175	0.7530	2.6812	-0.421	336.81	-0.47	15
6.0170	0.7530	2.6811	-0.425	336.72	-0.50	17
6.0157	0.7529	2.6778	-0.548	336.67	-0.51	19
6.0135	0.7529	2.6769	-0.581	336.33	-0.62	21
6.0120	0.7524	2.6729	-0.730	335.94	-0.73	25
6.0090	0.7521	2.6691	-0.870	335.49	-0.86	29
6.0080	0.7522	2.6693	-0.860	335.44	-0.88	34
6.0085	0.7520	2.6681	-0.910	334.91	-1.04	39
6.0010	0.7524	2.6680	-0.913	334.25	-1.23	44
6.0010	0.7525	2.6688	-0.883	334.02	-1.30	48
6.0040	0.7534	2.6783	-0.538	333.60	-1.43	58
6.0100	0.7535	2.6798	-0.573	333.33	-1.50	68
6.0010	0.7539	2.6831	-0.350	332.60	-1.72	78

\* Original.

TABLE XXI.—*Alloy C. Cast in Sand.*

	Per Cent.
Carbon . . . . .	3.08
Silicon . . . . .	0.172
Manganese . . . . .	0.13
Sulphur . . . . .	0.019
Phosphorus . . . . .	0.010

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*6.0787	0.7574	2.7384	...	344.16	...	...
6.0775	0.7573	2.7370	-0.051	343.88	-0.08	2
6.0750	0.7568	2.7325	-0.216	343.72	-0.12	4
6.0715	0.7565	2.7285	-0.364	343.51	-0.18	8
6.0700	0.7563	2.7266	-0.433	343.49	-0.19	9
6.0700	0.7566	2.7284	-0.367	...	...	10
6.0675	0.7562	2.7246	-0.506	343.06	-0.32	11
6.0672	0.7570	2.7301	-0.304	343.02	-0.33	12
6.0660	0.7562	2.7242	-0.518	342.79	-0.40	13
6.0650	0.7563	2.7243	-0.516	...	...	14
6.0642	0.7557	2.7197	-0.683	342.64	-0.44	15
6.0630	0.7556	2.7186	-0.725	342.57	-0.46	17
6.0620	0.7553	2.7157	-0.831	342.33	-0.53	19
6.0600	0.7553	2.7148	-0.904	342.23	-0.56	21
6.0577	0.7549	2.7114	-0.990	341.90	-0.65	25
6.0555	0.7557	2.7152	-0.850	341.48	-0.78	29
6.0540	0.7563	2.7188	-0.718	341.61	-0.74	34
6.0490	0.7566	2.7190	-0.710	340.96	-0.93	39
6.0420	0.7555	2.7080	-1.110	340.57	-1.04	44
6.0400	0.7564	2.7000	-1.400	340.37	-1.10	48
6.0350	0.7552	2.6900	-1.762	340.06	-1.19	58
6.0350	0.7555	2.7000	-1.405	340.09	-1.18	68
6.0230	0.7585	2.7200	-1.675	340.05	-1.19	78

\* Original.

TABLE XXII.—*Alloy D. Cast in Sand.*

	Per Cent.
Carbon . . . . .	2.59
Silicon . . . . .	0.146
Manganese . . . . .	0.12
Sulphur . . . . .	0.016
Phosphorus . . . . .	0.012

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*6.0110	0.7484	2.6442	...	333.08	...	...
6.0097	0.7486	2.6445	+0.011	332.81	-0.08	2
6.0080	0.7484	2.6429	-0.049	332.66	-0.12	4
6.0055	0.7478	2.6363	-0.368	332.46	-0.18	8
6.0030	0.7475	2.6341	-0.383	332.42	-0.19	9
6.0035	0.7481	2.6383	-0.224	...	...	10
6.0010	0.7475	2.6332	-0.418	332.01	-0.32	11
6.0000	0.7480	2.6364	-0.295	331.97	-0.33	12
5.9990	0.7473	2.6311	-0.496	331.77	-0.39	13
5.9980	0.7476	2.6325	-0.428	...	...	14
5.9970	0.7469	2.6272	-0.645	331.63	-0.43	15
5.9955	0.7471	2.6276	-0.630	331.57	-0.45	17
5.9940	0.7473	2.6289	-0.580	331.36	-0.52	19
5.9920	0.7474	2.6286	-0.592	331.23	-0.55	21
5.9890	0.7467	2.6219	-0.810	330.98	-0.64	25
5.9850	0.7466	2.6195	-0.937	330.63	-0.73	29
5.9810	0.7467	2.6184	-0.980	330.57	-0.75	34
5.9760	0.7466	2.6156	-1.085	330.30	-0.83	39
5.9690	0.7474	2.6186	-0.975	330.09	-0.90	44
5.9640	0.7478	2.6210	-0.920	329.98	-0.92	48
5.9365	0.7473	2.6000	-1.675	329.76	-0.99	58
5.9295	0.7481	2.6000	-1.675	329.74	-1.00	68
5.9115	0.7507	2.6200	-0.915	329.12	-1.19	78

\* Original.



TABLE XXIII.—*Alloy E. Cast in Sand.*

						Per Cent.
Carbon	.	.	.	.	.	1.96
Silicon	.	.	.	.	.	0.215
Manganese	.	.	.	.	.	0.20
Sulphur	.	.	.	.	.	0.013
Phosphorus	.	.	.	.	.	0.015

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*6.0580	0.7507	2.6797	...	329.36	...	...
6.0550	0.7512	2.6835	+0.142	329.00	-0.11	2
6.0535	0.7510	2.6808	+0.041	328.82	-0.16	4
6.0507	0.7503	2.6744	-0.198	328.61	-0.22	8
6.0480	0.7502	2.6732	-0.243	328.59	-0.23	9
6.0480	0.7506	2.6756	-0.153	...	...	10
6.0460	0.7503	2.6729	-0.254	328.22	-0.34	11
6.0455	0.7507	2.6755	-0.157	328.19	-0.35	12
6.0445	0.7502	2.6714	-0.310	328.02	-0.41	13
6.0435	0.7502	2.6710	-0.325	...	...	14
6.0420	0.7500	2.6687	-0.411	327.84	-0.46	15
6.0400	0.7500	2.6678	-0.444	327.78	-0.48	17
6.0377	0.7500	2.6665	-0.439	327.54	-0.55	19
6.0350	0.7507	2.6704	-0.348	327.44	-0.58	21
6.0310	0.7507	2.6687	-0.411	327.11	-0.68	25
6.0270	0.7503	2.6639	-0.590	326.70	-0.81	29
6.0230	0.7504	2.6633	-0.612	326.62	-0.83	34
6.0200	0.7517	2.6710	-0.325	326.43	-0.89	39
6.0140	0.7539	2.6846	-0.421	325.68	-1.12	44
6.0090	0.7538	2.6800	-0.422	325.58	-1.15	48
6.0010	0.7525	2.6600	-0.512	325.01	-1.32	58
5.9800	0.7510	2.6500	-1.150	324.71	-1.41	68
†5.9650	0.7562	2.6790	-0.026	324.53	-1.47	78

\* Original.

† Scaled.

TABLE XXIV.—*Alloy F. Cast in Sand.*

	Per Cent.
Carbon . . . . .	1.58
Silicon . . . . .	0.168
Manganese . . . . .	0.17
Sulphur . . . . .	0.015
Phosphorus . . . . .	0.014

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*5-9350	0.7983	2.9704	...	376.21	...	...
5-9322	0.7978	2.9648	-0.188	375.59	-0.17	2
5-9290	0.7980	2.9650	-0.182	375.37	-0.22	4
5-9230	0.7971	2.9555	-0.500	375.06	-0.30	8
5-9230	0.7971	2.9555	-0.500	375.01	-0.32	9
5-9210	0.7976	2.9581	-0.415	...	...	10
5-9160	0.7968	2.9497	-0.604	374.51	-0.45	11
5-9160	0.7968	2.9497	-0.604	374.47	-0.46	12
5-9110	0.7968	2.9473	-0.775	374.20	-0.53	13
5-9100	0.7969	2.9473	-0.775	...	...	14
5-9067	0.7966	2.9429	-0.921	374.00	-0.58	15
5-9030	0.7973	2.9467	-0.880	373.90	-0.61	17
5-8990	0.7966	2.9394	-1.040	373.57	-0.70	19
5-8955	0.7970	2.9404	-1.002	373.49	-0.72	21
5-8890	0.7974	2.9403	-1.008	373.24	-0.79	25
5-8625	0.7979	2.9304	-1.340	372.55	-0.97	29
†5-8625	0.8004	2.9491	-0.774	373.23	-0.79	34
†5-8575	0.8020	2.9583	-0.405	373.82	-0.64	39

\* Original.

† Scaled.

TABLE XXV.—*Alloy G. Cast in Sand.*

						Per Cent.
Carbon . . . . .						0.99
Silicon . . . . .						0.233
Manganese . . . . .						0.19
Sulphur . . . . .						0.015
Phosphorus . . . . .						0.012

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*5.9490	0.7683	2.7579	...	352.59	...	...
5.9470	0.7684	2.7576	-0.010	352.17	-0.12	2
5.9380	0.7690	2.7576	-0.010	352.00	-0.18	4
5.9375	0.7679	2.7492	-0.316	351.75	-0.24	8
5.9350	0.7677	2.7467	-0.406	351.74	-0.24	9
5.9335	0.7689	2.7546	-0.120	...	...	10
5.9310	0.7683	2.7496	-0.300	351.46	-0.32	11
5.9280	0.7680	2.7458	-0.440	351.34	-0.34	12
5.9255	0.7684	2.7474	-0.380	351.26	-0.38	13
5.9250	0.7681	2.7450	-0.470	...	...	14
5.9215	0.7678	2.7414	-0.600	351.09	-0.42	15
5.9185	0.7684	2.7441	-0.500	351.01	-0.45	17
5.9125	0.7684	2.7413	-0.603	350.82	-0.50	21
5.9040	0.7685	2.7382	-0.718	350.59	-0.57	25
5.8795	0.7690	2.7302	-1.005	350.32	-0.64	29
5.8735	0.7686	2.7244	-1.220	350.39	-0.62	34
†5.8730	0.7715	2.7450	-0.470	350.76	-0.52	39

\* Original.

† Scaled.

TABLE XXVI.—*Alloy H. Cast in Sand.*

	Per Cent.
Carbon . . . . .	0.55
Silicon . . . . .	0.182
Manganese . . . . .	0.20
Sulphur . . . . .	0.013
Phosphorus . . . . .	0.014

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*5.8910	0.7806	2.8294	...	354.92	...	...
5.8870	0.7804	2.8157	-0.450	354.72	-0.05	2
5.8850	0.7807	2.8171	-0.435	354.67	-0.07	4
5.8830	0.7806	2.8256	-0.135	354.57	-0.09	8
5.8820	0.7804	2.8133	-0.570	354.54	-0.13	9
5.8800	0.7808	2.8153	-0.499	...	...	10
5.8780	0.7809	2.8156	-0.489	354.40	-0.14	11
5.8770	0.7807	2.8133	-0.570	354.39	-0.14	12
5.8750	0.7809	2.8141	-0.540	354.31	-0.17	13
5.8750	0.7810	2.8142	-0.539	...	...	14
5.8740	0.7809	2.8137	-0.557	354.22	-0.19	15
5.8710	0.7809	2.8122	-0.609	354.19	-0.20	17
5.8690	0.7817	2.8160	-0.474	354.10	-0.23	19
5.8670	0.7817	2.8155	-0.494	354.09	-0.23	21
5.8610	0.7810	2.8074	-0.780	354.02	-0.25	25
5.8405	0.7824	2.8052	-0.858	353.80	-0.31	29
†5.8375	0.7837	2.8151	-0.507	354.30	-0.17	34

\* Original.

† Scaled.

TABLE XXVII.—*Alloy I. Cast in Sand.*

	Per Cent.
Carbon . . . . .	0.15
Silicon . . . . .	0.186
Manganese . . . . .	0.15
Sulphur . . . . .	0.040
Phosphorus . . . . .	0.017

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*6.0160	0.7502	2.6657	...	336.54	...	...
6.0177	0.7510	2.6667	+0.376	336.58	+0.01	2
6.0177	0.7510	2.6667	+0.376	336.56	+0.004	4
6.0147	0.7507	2.6617	-0.151	336.48	-0.02	8
6.0140	0.7507	2.6617	-0.151	336.47	-0.02	9
6.0125	0.7506	2.6603	-0.203	...	...	10
6.0130	0.7511	2.6637	-0.075	336.44	-0.03	11
6.0110	0.7511	2.6628	-0.109	336.44	-0.03	12
6.0120	0.7511	2.6633	-0.090	336.41	-0.04	13
6.0125	0.7513	2.6651	-0.022	...	...	14
6.0117	0.7509	2.6616	-0.155	336.39	-0.04	15
6.0105	0.7510	2.6618	-0.146	336.38	-0.04	17
6.0090	0.7517	2.6667	+0.376	336.34	-0.06	19
6.0070	0.7518	2.6665	+0.301	336.36	-0.05	21
6.0030	0.7519	2.6653	-0.015	336.33	-0.06	25
5.9975	0.7522	2.6650	-0.026	336.34	-0.06	29
5.9960	0.7522	2.6646	-0.041	336.48	-0.02	34
5.9950	0.7522	2.6641	-0.060	336.61	+0.02	39

\* Original.

It will be observed that a progressive diminution in weight took place throughout, except in the case of alloy I, where it was succeeded by an increase after the twenty-ninth heat.

Alloys B to I of the chill cast series behaved similarly to those of the sand cast series, even although there was a permanent shrinkage in only two out of the eight alloys. Alloys B to E all showed a shrinkage at the sixty-seventh heat. The authors think that the apparent slight permanent expansions recorded from E to I in the summary are caused by the scale, which naturally forms more plentifully on the lower carbon members, and which tends to loosen itself from the bar, and thus give too high a reading.

The only alloy which showed a permanent growth of any magnitude was A, and even this showed a shrinkage after thirty-four heats. A permanent expansion was recorded at the thirty-eighth heat, and in the next fifty-two heats the bar grew slowly but steadily until, at the ninetieth heat, a growth of 6.88 per cent. was obtained. At a later stage of the research the explanation of this behaviour was found. For the present the authors desire to omit this alloy from their consideration of this series. Their reasons and the explanation will be found on pp. 71-74.

Broadly speaking, then, pure iron-carbon alloys, whether chill or sand cast does not matter, do not expand permanently after repeated heatings, but on the contrary shrink. The amount of shrinkage is so small that, from a practical standpoint, it is almost if not quite negligible. The results obtained at this stage may be said to have given the authors the solution of their practical problem, viz. an alloy whose volume shows no tendency to change appreciably after numerous heatings to about 900° C. Such an alloy would be a white iron with about 3 per cent. of carbon and only small quantities of other constituents, of which for this purpose silicon is the most important. This alloy would shrink slightly on repeated heatings, but it would probably be not more than something of the order of 1 per cent. after one hundred heats. This type of shrinkage is usually ascribed to the gradual removal of contraction stresses set up in the originally cast metal. The loss of weight observed, which tends to diminish with decreasing

carbon content, is caused by the gradual oxidation of carbon by the furnace gases which penetrate into the muffle, and, as later experiments showed with other alloys, into the bars themselves. The real is no doubt greater than the apparent loss, because there is probably a simultaneous absorption of oxygen, which is evidently the explanation of the increase in weight of alloy I.

When it was found that alloys A to I, whether cast in chill or sand moulds, were white irons, four more alloys were made in which the carbon ranged from 4·6 to 3·0 per cent., and the silicon varied between 0·5 and 0·79 per cent. They also contained a considerable amount of manganese. They were cast in sand, the base of this series being a grey iron. The following is the complete analysis made:—

#### HIGH CARBON MEDIUM SILICON SERIES.

Alloy.	Percentage.				
	Carbon.	Silicon.	Manganese.	Sulphur.	Phosphorus.
J	4·60	0·79	1·26	0·018	0·016
K	3·90	0·69	1·09	0·019	0·021
L	3·60	0·65	1·02	0·018	0·017
M	3·02	0·50	0·86	0·018	0·017

The fracture of J showed a grey iron, except for a mottled area near the centre. K and L were almost entirely white irons, and contained only small amounts of graphite. M was a white iron. Test bars were ground to size in the same way as those of the A to I chill series. They were heated sixty-eight times; full details of the volume and weight changes of J, K, and L are given in Tables XXVIII. to XXX. These alloys grew steadily from the outset. Ultimate growth was reached in from fifty to sixty heats; it was greatest in J and least in L. The following table enables a comparison to be made:—

Alloy.	Percentage Growth after			Ultimate Growth.	Percentage Change of Weight.
	10 Heats.	19 Heats.	29 Heats.		
J	3.48	8.02	11.26	12.65	+0.21
K	2.35	6.10	7.80	10.35	-0.74
L	2.24	5.15	6.68	8.70	-1.05

After reaching a maximum growth the bars showed a tendency to contract slightly. It will be observed that the bar with the least silicon shows the least growth, and that with the highest silicon the greatest growth. Alloy M behaved differently from the above trio, and in a manner which recalled that of A under similar conditions. It contracted during the first ten heats (Table XXXI.), but after the eleventh heat it showed a growth, and this increased until a maximum value, viz. 6.2 per cent., was obtained after fifty-eight heats. The test bar of M had been cut from a part near the gate end of the casting. In order to see whether the same behaviour would be shown by a bar cut from another part of the casting, the top of one of the risers was selected, i.e. a part as far distant as possible from the other. This was subjected to similar heatings, and the results are given in Table XXXII. under the head of alloy MM. In this case the bar contracted up to the ninth heat. It was not measured after the tenth heat, but after the eleventh heat it was found to be expanding. The rate, however, was slower than in the case of M, and it was only after the fourteenth heat that the bar showed a growth as compared with the original size. The rate of growth remained slower, and the maximum growth, obtained after forty-seven heats, was only 2.54 per cent.

Apart from the difference in the amount of the ultimate growth, the fact of a contraction up to the ninth or tenth heat, followed by an expansion, was thus confirmed.

To account for this behaviour of alloys A and M, a hypothesis naturally suggested itself in view of the two main facts hitherto established by the research. These facts were:—

1. All the alloys examined, which did not contain graphite 1909.—ii.

E



TABLE XXVIII.—*Alloy J. Cast in Sand.*

	Per Cent.
Carbon . . . . .	4·60
Silicon . . . . .	0·79
Manganese . . . . .	1·26
Sulphur . . . . .	0·018
Phosphorus . . . . .	0·016

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*6·0930	0·9542	4·3571	...	579·22	...	...
6·1145	0·9596	4·4213	+1·47	579·00	-0·05	1 & 2
6·1225	0·9624	4·4523	+2·20	579·12	-0·01	4
6·1370	0·9642	4·4806	+2·83	579·64	+0·07	8
6·1485	0·9650	4·4963	+3·21	579·83	+0·10	9
6·1500	0·9673	4·5090	+3·48	...	...	10
6·1660	0·9689	4·5449	+4·31	580·10	+0·15	11
6·1720	0·9696	4·5561	+4·60	580·17	+0·16	12
6·1800	0·9716	4·5672	+4·85	580·27	+0·18	13
6·1875	0·9727	4·5973	+5·56	...	...	14
6·2000	0·9750	4·6289	+6·25	580·79	+0·27	15
6·2110	0·9768	4·6532	+6·83	580·79	+0·27	17
6·2360	0·9808	4·6094	+8·02	581·18	+0·34	19
6·2540	0·9832	4·7480	+9·10	581·28	+0·36	21
6·2870	0·9870	4·8101	+10·25	580·41	+0·20	25
6·2960	0·9883	4·8290	+10·85	579·45	+0·04	26
6·3060	0·9894	4·8474	+11·26	579·02	-0·03	29
6·3150	0·9949	4·9080	+12·85	581·08	+0·32	34
6·3230	0·9961	4·9268	+13·10	581·22	+0·34	39
6·3250	0·9963	4·9303	+13·20	580·29	+0·18	44
6·3200	0·9957	4·9500	+13·89	579·61	+0·07	48
6·3200	0·9950	4·9000	+12·65	577·92	-0·22	58
6·3210	0·9945	4·9000	+12·65	580·44	+0·21	68

\* Original.

TABLE XXIX.—*Alloy K. Cast in Sand.*

	Per Cent.
Carbon . . . . .	3·90
Silicon . . . . .	0·69
Manganese . . . . .	1·09
Sulphur . . . . .	0·019
Phosphorus . . . . .	0·021

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*5·9827	0·9384	4·1370	...	603·35	...	...
5·9900	0·9403	4·1657	+0·68	602·80	-0·09	1 & 2
6·0100	0·9421	4·1889	+1·24	602·59	-0·12	4
6·0250	0·9431	4·2084	+1·72	602·28	-0·17	8
6·0250	0·9436	4·2100	+1·75	602·23	-0·18	9
6·0360	0·9452	4·2348	+2·35	...	...	10
6·0620	0·9480	4·2785	+3·41	601·70	-0·27	11
6·0700	0·9500	4·3024	+4·00	601·65	-0·28	12
6·0835	0·9517	4·3171	+4·35	601·32	-0·33	13
6·0900	0·9526	4·3397	+4·89	...	...	14
6·0965	0·9543	4·3602	+5·40	601·07	-0·38	15
6·1020	0·9547	4·3678	+5·59	600·97	-0·39	17
6·1117	0·9563	4·3894	+6·10	600·66	-0·34	19
6·1170	0·9577	4·4060	+6·50	600·45	-0·48	21
6·1250	0·9600	4·4332	+7·16	600·22	-0·52	25
6·1290	0·9604	4·4390	+7·30	599·93	-0·56	26
6·1340	0·9620	4·4581	+7·80	599·40	-0·65	29
6·1410	0·9631	4·5007	+8·80	600·09	-0·54	34
6·1500	0·9694	4·5380	+9·70	600·83	-0·42	39
6·1510	0·9697	4·5398	+9·91	600·10	-0·54	44
6·1520	0·9701	4·5400	+9·75	598·78	-0·70	48
6·1550	0·9727	4·5700	+10·45	598·45	-0·81	58
6·1530	0·9732	4·5650	+10·35	598·86	-0·74	68

\* Original.

TABLE XXX.—*Alloy L. Cast in Sand.*

	Per Cent.
Carbon . . . . .	3·60
Silicon . . . . .	0·65
Manganese . . . . .	1·02
Sulphur . . . . .	0·018
Phosphorus . . . . .	0·017

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*6·1870	0·9516	4·3995	...	619·20	...	...
6·2140	0·9544	4·4448	+1·03	618·50	-0·11	1 & 2
6·2160	0·9559	4·4599	+1·13	618·28	-0·14	4
6·2290	0·9564	4·4742	+1·69	618·06	-0·18	8
6·2320	0·9566	4·4783	+1·79	618·02	-0·19	9
6·2390	0·9581	4·4976	+2·24	...	...	10
6·2565	0·9603	4·5309	+3·02	617·54	-0·26	11
6·2600	0·9613	4·5428	+3·34	617·49	-0·28	12
6·2700	0·9625	4·5614	+3·72	617·21	-0·31	13
6·2750	0·9635	4·5744	+3·99	...	...	14
6·2800	0·9642	4·5850	+4·22	616·95	-0·35	15
6·2850	0·9654	4·5993	+4·55	616·86	-0·37	17
6·2950	0·9673	4·6255	+5·15	616·59	-0·43	19
6·2990	0·9689	4·6429	+5·52	616·43	-0·44	21
6·3080	0·9713	4·6735	+6·25	616·13	-0·49	25
6·3100	0·9715	4·6769	+6·32	615·79	-0·55	26
6·3140	0·9729	4·6925	+6·68	615·44	-0·60	29
6·3200	0·9762	4·7298	+7·51	615·90	-0·53	34
6·3250	0·9774	4·7443	+7·75	616·04	-0·51	39
6·3230	0·9790	4·7593	+8·19	615·24	-0·64	44
6·3250	0·9787	4·7700	+8·68	614·61	-0·74	48
6·3240	0·9809	4·7800	+8·69	613·60	-0·91	58
6·3230	0·9816	4·7500	+8·70	612·67	-1·05	68

\* Original.

TABLE XXXI.—*Alloy M. Cast in Sand.*

This bar was cut from a part near the gate end of the casting.  
(Compare the same metal MM.)

	Per Cent.
Carbon . . . . .	3.02
Silicon . . . . .	0.50
Manganese . . . . .	0.86
Sulphur . . . . .	0.018
Phosphorus . . . . .	0.017

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*6-1317	0.9625	4.4608	...	616.88	...	...
6-1270	0.9625	4.4573	-0.0785	616.13	-0.12	1 & 2
6-1240	0.9627	4.4570	-0.095	615.86	-0.16	4
6-1220	0.9630	4.4586	-0.0495	615.49	-0.22	8
6-1180	0.9625	4.4508	-0.225	615.41	-0.24	9
6-1180	0.9625	4.4508	-0.225	...	...	10
6-1280	0.9630	4.4630	+0.049	614.87	-0.30	11
6-1280	0.9638	4.4693	+0.190	614.74	-0.34	12
6-1345	0.9640	4.4769	+0.360	614.45	-0.39	13
6-1370	0.9646	4.4836	+0.510	...	...	14
6-1415	0.9652	4.4925	+0.710	614.17	-0.44	15
6-1455	0.9656	4.4991	+0.860	614.03	-0.46	17
6-1540	0.9673	4.5219	+1.300	613.70	-0.51	19
6-1650	0.9694	4.5491	+1.90	613.52	-0.54	21
6-1860	0.9724	4.5931	+2.90	613.20	-0.59	25
6-1930	0.9739	4.6113	+3.10	612.86	-0.65	26
6-1955	0.9756	4.6305	+3.80	612.43	-0.72	29
6-2070	0.9786	4.6676	+4.60	612.85	-0.65	34
6-2130	0.9807	4.6920	+5.10	613.42	-0.56	39
6-2140	0.9812	4.6984	+5.30	612.07	-0.78	44
6-2130	0.9820	4.7051	+5.40	611.37	-0.80	48
6-2050	0.9847	4.7400	+6.20	610.04	-1.11	58
6-2040	0.9850	4.7400	+6.20	609.95	-1.12	68

\* Original.

TABLE XXXII.—*Alloy MM. Cast in Sand.*

This bar was cut from the top of a riser as far as possible from the gate.  
(Compare the same metal M.)

	Per Cent.
Carbon . . . . .	3.02
Silicon . . . . .	0.50
Manganese . . . . .	0.86
Sulphur . . . . .	0.018
Phosphorus . . . . .	0.017

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*6.0400	0.9600	4.3717	...	598.97	...	...
6.0340	0.9604	4.3704	-0.029	598.67	-0.05	1
6.0330	0.9600	4.3666	-0.116	598.22	-0.12	2
6.0320	0.9599	4.3641	-0.174	598.01	-0.16	3
6.0320	0.9599	4.3629	-0.210	597.76	-0.20	4
6.0330	0.9599	4.3636	-0.185	597.07	-0.21	5
6.0330	0.9599	4.3636	-0.185	597.66	-0.22	6
6.0315	0.9599	4.3625	-0.211	597.60	-0.23	7
6.0310	0.9597	4.3622	-0.217	597.42	-0.26	9
6.0300	0.9602	4.3663	-0.123	597.29	-0.28	11
6.0300	0.9600	4.3645	-0.160	597.23	-0.29	12
6.0300	0.9600	4.3645	-0.160	597.17	-0.30	13
6.0307	0.9610	4.3741	+0.054	597.11	-0.31	14
6.0325	0.9612	4.3750	+0.075	596.99	-0.33	15
6.0350	0.9615	4.3760	+0.114	596.85	-0.35	16
6.0380	0.9611	4.3803	+0.229	596.76	-0.37	17
6.0390	0.9614	4.3850	+0.345	596.73	-0.37	18
6.0400	0.9622	4.3900	+0.457	596.67	-0.38	19
6.0430	0.9627	4.3950	+0.549	596.61	-0.39	20
6.0440	0.9622	4.3920	+0.480	596.55	-0.40	21
6.0475	0.9630	4.4000	+0.680	596.46	-0.42	22
6.0520	0.9636	4.4050	+0.780	596.41	-0.42	23
6.0540	0.9639	4.4100	+0.915	596.38	-0.43	24
6.0560	0.9642	4.4250	+1.220	596.33	-0.44	26
6.0600	0.9650	4.4300	+1.370	596.25	-0.45	28
6.0635	0.9654	4.4400	+1.700	596.16	-0.47	30
6.0640	0.9658	4.4410	+1.830	596.12	-0.47	31
6.0690	0.9668	4.4500	+1.900	595.99	-0.49	34
6.0710	0.9671	4.4590	+2.010	595.94	-0.50	35
6.0725	0.9671	4.4600	+2.060	595.91	-0.51	37
6.0765	0.9680	4.4700	+2.280	595.82	-0.52	39
6.0780	0.9684	4.4710	+2.291	595.77	-0.53	42
6.0800	0.9686	4.4750	+2.380	595.77	-0.53	44
6.0810	0.9693	4.4800	+2.520	595.72	-0.54	45
6.0830	0.9696	4.4820	+2.540	595.73	-0.54	47
6.0860	0.9700	4.4830	+2.542	595.73	-0.54	59

\* Original.

or free carbon in some form, did not grow, but actually contracted to a greater or less extent (alloys B to I).

2. All the alloys examined, which contained graphite, grew (alloys PH, NIP, J, K, and L).

The natural hypothesis to account for the behaviour of A and M was to assume that these alloys, originally white irons, contracted as long as they remained white, but that after a time they deposited free carbon, probably as temper carbon, and that this, either directly or indirectly, caused their growth. This hypothesis was tested in the following way:—

Short pieces of bars A and M were heated along with the main bars. Samples for chemical analysis were turned from these pieces, beginning with a heat at which contraction was still taking place, and following the heats through the point at which contraction ceased and expansion began. Each sample was tested for temper carbon, and if a positive result was obtained, a quantitative estimation was made by the usual method.

In the case of alloy M analyses showed that up to and including the ninth heat no temper carbon was present. Beyond this it was readily detected, and it increased with the progression of the heats. This is illustrated by the following figures:—

No. of Heat.	Volume Change.	Percentage Temper Carbon.
1-9	Shrinkage	nil.
10	Growth	0·049
12	More growth	0·203
19	Still more growth	0·689

With alloy A no temper carbon was detected up to the eighteenth heat. It was found in minute amount after the nineteenth heat, and increased in the twenty-first and twenty-second heats, the absolute quantities, however, being much smaller than in the case of M. If Table XI. be compared it will be found that up to the nineteenth heat alloy A contracted, and that after this the contraction diminished, *i.e.* a slight expansion set in. This was followed by a contraction between the twenty-fourth and twenty-sixth heats, and

again succeeded by an expansion, which, however, only attained a positive value at the thirty-eighth heat. Obviously in this case the rate of formation of temper carbon was much slower than in M, and while it does not furnish so good a test, it bears out the results obtained with that alloy.

The change from shrinkage to growth under repeated heatings in the case of alloys A and M was thus shown to coincide with the appearance of free carbon, probably temper carbon. Free carbon was in this way proved to be in some way an indispensable factor in the growth of cast iron under these conditions. This fact is of fundamental importance.

Some time before the previous experiments were concluded it had become evident that the influence of silicon must be thoroughly investigated. Of the alloys hitherto tested all those containing 0.65 per cent. of this element grew from the outset, the largest growth being obtained with the highest silicon. The next series of alloys was designed so as to contain a constant quantity of carbon, about 4 per cent., and ascending percentages of silicon from 1 to 6 by steps of 1. Manganese, sulphur, and phosphorus were to be kept as low as possible. The reason for this choice was as follows: It was argued that the earlier members of the series would contain some "combined" carbon, and that the later would contain all their carbon in the "graphitic" condition; that by repeated heating, the former would tend to deposit their combined as "temper" carbon, and that if the "growth of cast iron" was due to an expansion consequent on this chemical change, the earlier members should grow and the later ones should not. It was obvious that such a series would also test whether growth was proportional to the percentage of silicon.

As regards the former alternative, it was mentioned on p. 31 that Mr. Outerbridge has denied that the deposition of graphite has any influence on the growth of the iron tested by him, without, however, giving any reasons. The following calculation gives an idea of the volume change that may be expected to occur when cementite decomposes into ferrite and temper carbon. The uncertainty attaching to the calculation arises from the fact that accurate data as to the specific gravity of "temper carbon" are not available. Assuming for

the moment that the specific gravity is the same as that of graphite, the volume change can be deduced as follows:—

Specific gravity of $\text{Fe}_3\text{C}$ at	16° C. = 7.07
„ „ Fe at	16° C. = 7.86
„ „ Graphite at 17° C. =	2.10
$\text{Fe}_3\text{C} \rightarrow 3\text{Fe} + \text{C}$	
Weight (grams)	180 $\rightarrow$ 168 + 12
Volume (cubic centimetres)	25.46 $\rightarrow$ 21.37 + 5.71
<i>i.e.</i> 25.46 cubic centimetres become 27.08 cubic centimetres.	
Volume increase =	6.36 per cent. (A)

If, however, the specific gravity of temper carbon is less than that of graphite, and approximates more to the pulverulent form of carbon, viz. charcoal, a higher value is obtained. Taking 1.45, which is the lowest figure obtained for charcoal, what may be termed the maximum value for the expansion consequent on this change is obtained thus:—

$\text{Fe}_3\text{C} \rightarrow 3\text{Fe} + \text{C}$	
Weight (grams)	180 $\rightarrow$ 168 + 12
Volume (cubic centimetres)	25.46 $\rightarrow$ 21.37 + 8.28
<i>i.e.</i> 25.46 cubic centimetres become 29.65.	
Volume increase =	16.46 per cent. (B)

These calculations do not give more than the order of magnitude of the volume increase, and they refer, of course, to 100 per cent.  $\text{Fe}_3\text{C}$ , which not even a white iron contains. They are, however, important, because they may account for the growths of A and M observed.

A contained originally 4.03 per cent. of combined carbon, which corresponds to about 60.45 per cent.  $\text{Fe}_3\text{C}$ . If a complete conversion of this to iron and temper carbon be assumed after ninety heats, then,

according to calculation A there would be a growth of	3.84 per cent.
„ „ B „ „	9.95 „

The found value, 6.88 per cent., falls between these, and, in fact, is exactly the mean of the two (6.89).

Again, M contained 3.02 per cent. combined carbon corresponding to 45.3 per cent.  $\text{Fe}_3\text{C}$ . Assuming a complete decomposition, then,

according to calculation A there would be a growth of	2.88 per cent.
„ „ B „ „	7.45 „

The maximum growth found for M was 6.20, and for MM



2.54 per cent. These values differ somewhat widely. But that for M falls within, and that for MM well below, the two calculated values.

Accordingly it does not appear as if the influence of this change on the growth of white irons, which become grey on heating, could be disregarded, as it has been by Mr. Outerbridge. The authors' opinion is that it may account for it so far as the present state of knowledge of the subject enables a view to be held. They recognise, however, that when more accurate data are available, the above calculations may need considerable revision.

#### IRON-CARBON-SILICON SERIES.

The analysis of the alloys designed to test more specifically the part played by silicon is as follows:—

TABLE XXXIIA.

Alloy.	Percentage.						
	Total Carbon.	Combined Carbon.	Graphite.	Silicon.	Manganese.	Sulphur.	Phosphorus.
N	3.98	0.64	3.34	1.07	0.25	0.010	0.013
O	3.98	0.68	3.30	1.79 <sup>+</sup>	0.23	0.010	0.013
P	3.79	0.30	3.49	2.96	0.25	0.010	0.012
Q	3.76	nil	3.76	4.20 <sup>-</sup>	0.27	0.010	0.012
R	3.79	nil	3.79	4.83 <sup>+</sup>	0.30	0.010	0.012
S	3.38	nil	3.38	6.14	0.30	0.010	0.013

It will be observed that the total carbon in the series is approximately constant, that alloys N and O contain about the same amount of combined carbon, that alloy P contains about half the quantity, and that the remaining alloys contain none at all. The silicon in O and R is 0.2 per cent. lower, in Q 0.2 per cent. higher than was desired. The remaining constituents are satisfactorily low and constant.

It is with this series that the authors have carried out most experiments, and from it they have derived the most information as to the cause or causes at work in the permanent expansion of cast irons after repeated heatings.

FIRST SERIES OF EXPERIMENTS WITH ALLOYS  
N TO S.

Test-pieces, 6 inches by about 0·88 of an inch, were machined from the castings. They were not taken from similar positions throughout, but haphazard, some from the gate, others from a riser either near to or at some distance from the gate. When the growth of these alloys was investigated it quickly became evident that the position from which a test-piece had been cut had a considerable influence on its rate of expansion. It was found that specimens taken from the gate end of the casting grew more rapidly than those taken from the top of a riser. Information as to the behaviour of the six specimens is contained in the following summary:—

*Alloy N (test-piece cut from a riser at some distance from the gate).*—This was an iron with a fine close grain. Under heat treatment it grew steadily, and reached its maximum growth in about sixteen heats. It did not crack, and retained its cylindrical form to the end.

*Alloy O (position from which the test-piece was cut is uncertain).*—This iron was very similar to N, except that the grain was coarser. Slight cracks developed over the entire surface after the twelfth heat. These enlarged somewhat after the fourteenth heat, but thereafter remained comparatively constant. Maximum growth was reached in about sixteen heats.

*Alloy P (test-piece cut from the bottom of the gate).*—This appeared to be a very "open" iron, but it retained its cylindrical shape almost perfectly throughout the heat treatment, and did not crack. It grew very rapidly at the outset—25·2 per cent. in five heats—after which the rate diminished considerably. Maximum growth was reached in about sixteen heats.

*Alloy Q (test-piece cut from a riser).*—This was an open-grained iron. After the third heat it was noticed that the ends were larger than the central part of the sample. At a later stage, however, the centre "caught up" this increased growth. This fact was noticed with other specimens, and is

explained on p. 112. After the sixth heat the bar was bent; after the eighth it was badly bent. Cracks developed at the twelfth heat, and these continued to enlarge. After the fifteenth heat accurate measurements were impossible to carry out. Nevertheless the heats were continued, because the bar continued to increase in weight. After fifty-two heats an approximate determination of the growth was obtained by measuring the circumference of the bar, and making an allowance for the cracks. The result showed that very little growth had taken place after the fifteenth heat. This bar grew much more slowly than P.

*Alloy R (test-piece cut from a riser).*—This alloy was very similar in appearance to Q, and behaved very similarly under heat treatment. Cracks appeared at the twelfth heat, and accurate measurements had to be abandoned after the thirteenth heat. An approximate measurement after the fifty-second heat was made.

*Alloy S (test-piece cut from the bottom of the gate).*—After the first heat a circular crack developed at one end, the outer  $\frac{1}{8}$  inch circumference cracking away from the core. After the second heat enormous cracks developed, the largest being  $\frac{5}{16}$  inch wide. After the sixth heat this had increased to about  $\frac{1}{2}$  inch, and the sample broke in two pieces at the centre while being handled. Thirty-two heats were carried through, and small particles constantly disengaged themselves from the cracked surfaces, thus rendering the measurements of weight too low. An approximate volume determination was made by the method indicated under Q. It is the most uncertain of the series, but it was possible to check it at a later stage of the investigation (p. 110), and it is probably within 5 per cent. of the exact value.

Complete measurements of the volume changes are contained in Tables XXXIV. to XXXIX. The results are also plotted in Fig. 1 (Plate III.), the co-ordinates being percentage growth and number of heats. In this way the rate of growth is clearly seen. In the case of N, O, and P the curves are plotted from the data obtained. It will be observed that the growth is rapid at first, diminishes after about the seventh heat, and stops at the sixteenth heat.

In the case of Q and R curves are plotted in full lines from the data obtained up to the point at which cracks appeared, viz. the twelfth heat. Beyond this the direction of the curves can only be guessed, and this is indicated by dotted lines. Attention is directed to the fact that the initial rate of growth of P is much greater than that of Q or R, and that it is only surpassed by them after the twelfth and tenth heat respectively. The data for plotting a curve of the rate of growth of S are insufficient. The appearance of the bars after maximum growth is reached is seen in the upper half of Plate II. To enable a comparison of the growth to be made, a bar of the original size is included on the left hand. It will be observed that N, O, and P have kept their cylindrical form in spite of a growth of 32·85 per cent. in the last case, and that Q, R, and S are increasingly distorted under the heat treatment given. The following table summarises the results:—

TABLE XXXIIB.

Alloy.	Percentage Silicon.	Percentage Growth on Heating.
N	1·07	15·40
O	1·79	23·46
P	2·06	32·85
Q	4·20	43·9
R	4·83	59·5
S	6·14	63·0

It is quite clear from these tests that silicon is a most important constituent of cast iron from the standpoint of growth under repeated heatings. If the ultimate growths and percentages of silicon are plotted as co-ordinates, the curve in Fig. 2 is obtained, which shows that, broadly speaking, the growth is proportional to the percentage of silicon, although the value for R seems relatively higher than those of the other five alloys. The growths are far in excess of those that could be caused by the conversion of combined into free carbon. Alloy N contained originally 0·64 per cent. combined carbon, corresponding to 9·6 per cent.  $\text{Fe}_3\text{C}$ . The complete decomposition of this in accordance with

A (p. 73) would cause a growth of 0·61 per cent.

B (p. 73) „ „ 1·58 „

Either of these is inadequate to account for the 15.4 per cent. growth found. The same obviously holds even more strongly for alloys O and P.

The fact that the two alloys P and S, which had been cut from the gate, grew more rapidly than the remaining four, which had not, pointed to an agent which had hitherto been left out of consideration, viz. the gas contained in the original casting, and perhaps also the gases in contact with the test-pieces

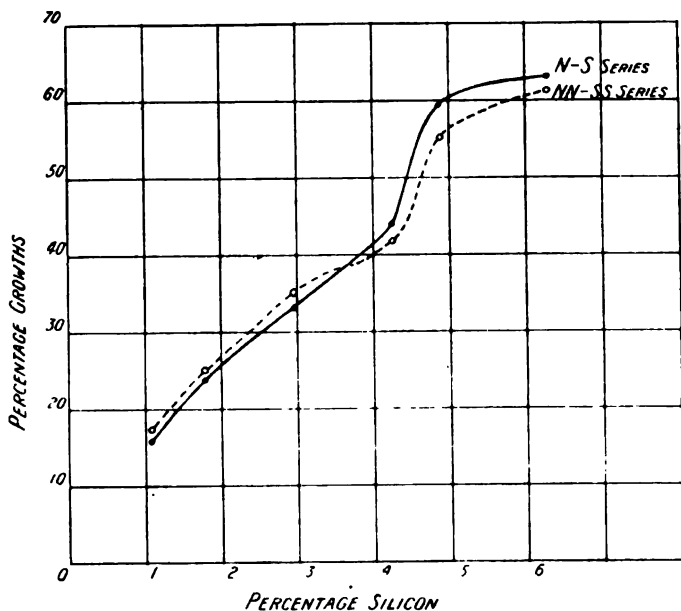


FIG. 2.—Alloys N to S. Curves illustrating the Relation between Percentage Growth and Percentage Silicon.

in the muffle. The gate of a casting is, as a rule, more "open" and contains more gas than the risers, and the next step in the investigation consisted in testing bars which were, as far as possible, comparable with one another from the standpoint of their gas content. Accordingly another set of bars was machined, each test-piece being taken from the top of a riser—that is, as far as possible from the gate. This series is indicated with double letters, except in the case of O, which is marked with a triple letter.

## DOUBLE-LETTERED SERIES, NN TO SS. VOLUME CHANGES.

These samples grew under heat treatment, and reached approximately the same ultimate growth as did the corresponding members of the previous series, but the rate of growth was in all cases slower. Cracks did not develop in QQ and RR until after the eighteenth heat, as compared with twelve heats in the single-letter series. But the most marked difference was shown by SS, which did not develop cracks until after the eighteenth heat, whereas S cracked after the first heat. Further, although SS cracked extensively (see Plate II.) before ultimate growth was reached, the cracks never became so large, nor was the specimen as much deformed. These results can be most simply explained by supposing that the castings contain their dissolved gas unevenly distributed, the gate containing the maximum and the top of a riser the minimum, and that the disruptive effects noticed in S were due to an excessive amount of dissolved gas.

It was further observed that the end of a sample nearest the gate always grew more rapidly during the earlier heats than the other end, but that ultimately the end farthest from the gate caught up and sometimes passed it. The following table illustrates this fact:—

TABLE XXXIII.

Heat No.	Alloy OOO.		Alloy QQ.		Alloy RR.	
	Far.	Near.	Far.	Near.	Far.	Near.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
3	1.92	2.44	1.53	1.65	1.54	1.94
10	6.30	6.08	7.40	6.83	7.37	6.73
15	7.28	6.55	8.20	8.20	9.15	7.98

NOTE.—The words "far" and "near" refer to positions with reference to the gate.

The more rapid growth of the end nearest the gate is explicable on the above supposition, viz. as being due to a larger amount of dissolved gas. It was the fact that the other end ultimately caught up and sometimes passed it, which led the authors to attribute this to the action of gases in contact with the specimens in the muffle. This point is dealt with later (see pp. 112–113).

TABLE XXXIV.—*Alloy N. Cast in Sand.*

	Per Cent.
Carbon . . . . .	3·98
Silicon . . . . .	1·07
Manganese . . . . .	0·25
Sulphur . . . . .	0·010
Phosphorus . . . . .	0·013

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Growth per Cent.	Weight. Grams.	Increase per Cent.	Heat No.
*5·992	0·8842	3·6790	...	457·23	...	...
6·028	0·8908	3·7566	2·10	457·44	0·04	1
6·056	0·8959	3·8170	3·76	458·15	0·20	2
6·080	0·8987	3·8559	4·81	458·40	0·27	3
6·114	0·9030	3·9154	6·43	459·32	0·45	4
6·158	0·9100	4·0048	8·88	460·55	0·72	5
6·184	0·9128	4·0461	10·00	461·40	0·89	6
6·203	0·9163	4·0899	11·26	461·75	0·99	7
6·216	0·9187	4·1199	12·10	461·90	1·02	8
6·230	0·9200	4·1410	12·60	461·88	1·01	9
6·240	0·9214	4·1600	13·10	461·86	1·00	10
6·251	0·9225	4·1775	13·50	461·79	0·99	11
6·259	0·9234	4·1810	13·90	462·00	1·04	12
6·266	0·9241	4·2038	14·25	461·58	0·95	13
6·272	0·9246	4·2103	14·50	461·62	0·95	14
6·280	0·9254	4·2233	14·80	460·75	0·76	15
6·282	0·9262	4·2315	15·10	460·46	0·70	16
6·283	0·9264	4·2341	15·15	460·29	0·66	17
6·283	0·9264	4·2341	15·15	460·26	0·65	18
6·284	0·9264	4·2347	15·16	460·19	0·64	19
6·281	0·9259	4·2287	14·90	459·89	0·57	21
6·280	0·9259	4·2276	14·86	460·00	0·60	23
6·279	0·9266	4·2450	15·40	459·95	0·59	24
6·280	0·9266	4·2450	15·40	460·34	0·65	25
6·279	0·9264	4·2300	15·00	460·26	0·65	26

\* Original.

TABLE XXXV.—*Alloy O. Cast in Sand.*

	Per Cent.
Carbon . . . . .	3·98
Silicon . . . . .	1·79
Manganese . . . . .	0·23
Sulphur . . . . .	0·010
Phosphorus . . . . .	0·013

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Growth per Cent.	Weight. Grams.	Increase per Cent.	Heat No.
5·9930	0·8856	3·6910	...	455·27	...	...
6·0400	0·8955	3·8039	3·00	455·99	0·16	1
6·1065	0·9048	3·9258	6·70	457·82	0·56	2
6·1420	0·9107	3·9996	8·70	458·84	0·78	3
6·2000	0·9203	4·1236	11·70	460·72	1·20	4
6·2755	0·9324	4·2842	16·10	463·17	1·73	5
6·3180	0·9375	4·3606	18·15	464·79	2·00	6
6·3450	0·9418	4·4192	19·80	465·58	2·26	7
6·3620	0·9437	4·4489	20·50	465·84	2·31	8
6·3790	0·9455	4·4780	21·40	466·20	2·41	9
6·3900	0·9466	4·4960	21·75	466·15	2·39	10
6·4000	0·9475	4·5120	22·20	466·35	2·44	11
6·4070	0·9480	4·5220	22·50	466·54	2·48	12
6·4130	0·9490	4·5359	22·90	465·83	2·32	13
6·4190	0·9490	4·5401	23·10	465·62	2·27	14
6·4250	0·9498	4·5514	23·40	464·55	2·04	15
6·4280	0·9504	4·5593	23·50	464·00	1·92	16
6·4270	0·9502	4·5573	23·45	463·82	1·88	17
6·4270	0·9504	4·5586	23·46	463·57	1·82	18
6·4300	0·9500	4·5575	23·45	463·57	1·82	19
6·4260	0·9500	4·5544	23·42	463·34	1·77	21
6·4240	0·9500	4·5533	23·41	463·31	1·77	23
6·4240	0·9500	4·5533	23·41	463·48	1·79	24
6·4270	0·9504	4·5550	23·43	463·94	1·90	25
6·4250	0·9500	4·5400	23·10	463·87	1·89	26

\* Original.



TABLE XXXVI.—*Alloy P. Cast in Sand.*

	Per Cent.
Carbon . . . . .	3.79
Silicon . . . . .	2.96
Manganese . . . . .	0.25
Sulphur . . . . .	0.010
Phosphorus . . . . .	0.012

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Growth per Cent.	Weight. Grams.	Increase per Cent.	Heat No.
*5.9950	0.8872	3.7055	...	449.54	...	...
6.093	0.9020	3.8934	5.19	451.32	0.41	1
6.216	0.9207	4.1386	11.70	455.41	1.32	2
6.288	0.9310	4.2802	15.60	458.22	1.93	3
6.374	0.9437	4.4586	21.50	461.54	2.67	4
6.450	0.9565	4.6343	25.20	464.72	3.37	5
6.483	0.9613	4.7037	27.00	466.00	3.67	6
6.506	0.9645	4.7519	28.10	466.52	3.78	7
6.518	0.9660	4.7763	29.00	466.77	3.84	8
6.536	0.9683	4.8124	30.10	467.10	3.91	9
6.540	0.9700	4.8324	30.60	467.27	3.95	10
6.551	0.9707	4.8467	30.90	467.50	4.00	11
6.560	0.9722	4.8708	31.50	467.58	4.02	12
6.565	0.9735	4.8856	31.90	467.43	4.00	13
6.568	0.9739	4.8901	32.10	467.26	3.95	14
6.572	0.9745	4.9007	32.30	466.22	3.72	15
6.578	0.9760	4.9210	32.80	465.80	3.62	16
6.576	0.9760	4.9196	32.65	465.55	3.67	17
6.579	0.9760	4.9217	32.85	465.61	3.58	18
6.577	0.9760	4.9202	32.75	465.58	3.57	19
6.575	0.9755	4.9134	32.50	465.33	3.51	21
6.577	0.9757	4.9169	32.60	465.48	3.54	23
6.576	0.9757	4.9169	32.60	465.45	3.55	24
6.581	0.9766	4.9200	32.75	466.02	3.67	25
6.582	0.9766	4.9200	32.75	465.79	3.62	26
6.582	0.9763	4.9200	32.75	465.95	3.66	27

\* Original.

TABLE XXXVII.—*Alloy Q. Cast in Sand.*

Carbon	Per Cent.
Silicon	3.76
Manganese	4.20
Sulphur	0.27
Phosphorus	0.010
	0.012

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Growth per Cent.	Weight. Grams.	Increase per Cent.	Heat No.
*6.0040	0.8806	3.6564	...	440.36	...	...
6.0390	0.8898	3.7550	2.70	441.56	0.27	1
6.0780	0.9018	3.8814	6.30	443.60	0.76	2
6.1100	0.9087	3.9629	8.80	444.78	1.00	3
6.1530	0.9164	4.0572	11.00	446.28	1.32	4
6.2090	0.9269	4.1885	14.60	448.19	1.78	5
6.2590	0.9297	4.2492	16.20	449.69	2.12	6
6.3010	0.9414	4.3848	20.00	451.32	2.49	7
6.3775	0.9464	4.4852	22.60	452.60	2.79	8
6.3820	0.9529	4.5503	24.50	453.36	2.95	9
6.4240	0.9564	4.6143	26.20	456.44	3.65	10
6.4580	0.9656	4.7279	29.20	457.86	3.97	11
6.4590	0.9718	4.8166	31.70	459.41	4.33	12
6.5530	0.9821	4.9632	36.00	461.25	4.74	13
6.6020	0.9922	5.1033	39.50	463.20	5.18	14
6.6170	1.0048	5.2433	43.10	463.80	5.31	15
...	...	...	...	464.47	5.49	16
...	...	...	...	464.84	5.56	17
...	...	...	...	465.16	5.63	18
...	...	...	...	465.35	5.69	19
...	...	...	...	466.04	5.83	21
...	...	...	...	466.33	5.90	23
...	...	...	...	466.43	5.92	24
...	...	...	...	466.58	5.97	25
...	...	...	...	466.70	6.00	26
...	...	...	...	466.59	5.97	27
...	...	...	...	466.65	5.98	28
...	...	...	...	467.04	6.01	29
...	...	...	...	467.85	6.26	31
...	...	...	...	469.20	6.58	33
...	...	...	...	469.77	6.78	34
...	...	...	...	472.12	7.20	37
...	...	...	...	473.84	7.60	39
...	...	...	...	474.97	7.80	41
...	...	...	...	476.72	8.26	43
...	...	...	...	477.67	8.40	45
...	...	...	...	479.03	8.80	47
...	...	...	...	480.52	9.10	49
6.76	0.995	5.25	43.9	482.42	9.59	52

\* Original.

TABLE XXXVIII.—*Alloy R. Cast in Sand.*

	Per Cent.
Carbon . . . . .	3.79
Silicon . . . . .	4.83
Manganese . . . . .	0.30
Sulphur . . . . .	0.010
Phosphorus . . . . .	0.012

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Growth per Cent.	Weight. Grams.	Increase per Cent.	Heat No.
*5.9970	0.8862	3.6983	...	435.00	...	...
6.0175	0.8990	3.8193	3.27	437.07	0.46	1
6.0555	0.9147	3.9796	7.61	439.62	1.06	2
6.0835	0.9210	4.0528	9.60	440.74	1.32	3
6.1310	0.9308	4.1709	12.80	442.65	1.76	4
6.2150	0.9427	4.3368	17.30	444.88	2.27	5
6.2760	0.9511	4.4584	19.80	446.73	2.70	6
6.3300	0.9619	4.5987	24.40	448.70	3.15	7
6.3760	0.9686	4.6959	27.00	450.26	3.51	8
6.4200	0.9780	4.8227	30.60	452.10	3.94	9
6.4720	0.9877	4.9575	34.10	454.14	4.40	10
6.5020	0.9903	5.0071	35.50	455.65	4.73	11
6.5400	1.0003	5.1358	39.00	457.05	5.08	12
6.6100	1.0169	5.3911	45.70	459.88	5.71	13
...	...	...	...	461.24	6.03	14
...	...	...	...	462.11	6.22	15
...	...	...	...	462.64	6.35	16
...	...	...	...	462.80	6.41	17
...	...	...	...	462.95	6.43	18
...	...	...	...	463.24	6.49	19
...	...	...	...	463.58	6.59	21
...	...	...	...	463.80	6.62	23
...	...	...	...	463.78	6.62	24
...	...	...	...	464.36	6.73	25
...	...	...	...	463.92	6.65	26
...	...	...	...	464.26	6.72	27
...	...	...	...	464.78	6.82	28
...	...	...	...	465.02	6.90	29
...	...	...	...	466.53	7.28	31
...	...	...	...	468.42	7.69	33
...	...	...	...	469.01	7.82	34
...	...	...	...	471.30	8.33	37
...	...	...	...	472.12	8.52	39
...	...	...	...	473.32	8.80	41
...	...	...	...	474.65	9.10	43
...	...	...	...	475.60	9.35	45
...	...	...	...	476.73	9.60	47
...	...	...	...	477.73	9.83	49
...	...	5.90	59.5	479.56	10.25	52

\* Original.

TABLE XXXIX.—*Alloy S. Cast in Sand.*

	Per Cent.
Carbon . . . . .	3.38
Silicon . . . . .	6.14
Manganese . . . . .	0.30
Sulphur . . . . .	0.010
Phosphorus . . . . .	0.013

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Growth per Cent.	Weight. Grams.	Increase per Cent.	Heat No.
*6.000	0.8884	3.7188	...	444.48	...	...
6.042	0.9035	4.3955	18.20	450.08	1.26	1
6.130	1.0350	5.1571	38.90	458.00	3.10	2
...	...	...	...	460.17	3.55	3
...	...	...	...	463.91	4.38	4
...	...	...	...	467.32	5.13	5
...	...	...	...	469.48	5.62	6
...	...	...	...	473.72	6.59	7
...	...	...	...	474.66	6.79	8
...	...	...	...	475.80	7.04	9
...	...	...	...	476.84	7.28	10
...	...	...	...	477.98	7.55	11
...	...	...	...	478.95	7.75	12
...	...	...	...	480.15	8.04	13
...	...	...	...	484.00	8.90	15
...	...	...	...	485.21	9.20	16
...	...	...	...	490.37	10.30	17
...	...	...	...	491.80	10.66	18
...	...	...	...	492.27	10.75	19
...	...	...	...	493.26	11.00	20
...	...	...	...	494.46	11.20	21
...	...	...	...	496.04	11.60	22
...	...	...	...	496.80	11.79	23
...	...	...	...	497.65	12.00	24
...	...	...	...	498.15	12.12	25
...	...	...	...	499.05	12.25	26
...	...	...	...	499.86	12.50	27
...	...	...	...	500.20	12.55	29
...	...	6.06	63	503.07	13.20	32

\* Original.

TABLE XL.—*Alloy NN. Cast in Sand.*

	Per Cent.
Carbon . . . . .	3·98
Silicon . . . . .	1·07
Manganese . . . . .	0·25
Sulphur . . . . .	0·010
Phosphorus . . . . .	0·013

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Growth per Cent.	Weight. Grams.	Increase per Cent.	Heat No.
*6·0090	0·8704	3·5747	...	447·81	...	...
6·0430	0·8726	3·6137	1·04	447·91	0·02	1
6·0640	0·8787	3·6766	2·83	448·25	0·09	2
6·0830	0·8818	3·7142	4·00	448·61	0·17	3
6·1160	0·8864	3·7735	5·89	449·37	0·35	4
6·1480	0·8912	3·8345	7·26	450·22	0·55	5
6·1860	0·8970	3·9089	9·36	451·57	0·84	6
6·2150	0·9016	3·9670	10·95	452·61	1·10	7
6·6380	0·9047	4·0097	12·20	453·32	1·23	8
6·2500	0·9065	4·0331	12·80	453·60	1·29	9
6·2630	0·9076	4·0515	13·40	453·68	1·32	10
6·2880	0·9105	4·0934	14·50	453·74	1·33	12
6·3070	0·9130	4·1285	15·50	453·66	1·31	14
6·3120	0·9133	4·1343	15·60	453·35	1·24	15
6·3180	0·9139	4·1433	15·90	453·30	1·22	16
6·3220	0·9145	4·1522	16·10	453·25	1·21	17
6·3240	0·9149	4·1600	16·40	452·89	1·13	18
6·3260	0·9153	4·1750	16·80	452·77	1·11	19
6·3275	0·9153	4·1760	16·81	452·77	1·11	20
6·3275	0·9153	4·1760	16·81	452·61	1·10	21
6·3250	0·9153	4·1750	16·80	452·38	1·02	22
6·3250	0·9150	4·1610	16·40	452·27	0·99	23
6·3270	0·9162	4·1700	16·65	452·48	1·04	25
6·3230	0·9162	4·1750	16·80	451·99	0·93	26

\* Original.

TABLE XLI.—*Alloy 000.*

	Per Cent.
Carbon . . . . .	3.98
Silicon . . . . .	1.79
Manganese . . . . .	0.23
Sulphur . . . . .	0.010
Phosphorus . . . . .	0.013

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Growth per Cent.	Weight. Grams.	Increase per Cent.	Heat No.
*5.9985	0.8877	3.7118	...	447.25	...	...
6.0416	0.8940	3.7919	2.32	447.55	0.06	1
6.0690	0.8985	3.8477	3.77	448.27	0.22	2
6.1070	0.9004	3.8477	4.62	449.28	0.45	3
6.1770	0.9145	4.0570	9.31	451.42	0.93	4
6.2370	0.9230	4.1741	12.50	453.51	1.40	5
6.2980	0.9325	4.3009	16.10	456.30	2.20	6
6.3360	0.9386	4.3832	18.15	457.89	2.39	7
6.3600	0.9433	4.4443	19.80	458.79	2.57	8
6.3760	0.9447	4.4683	20.40	458.97	2.62	9
6.3850	0.9457	4.4841	20.80	458.95	2.62	10
6.4080	0.9490	4.5323	22.20	459.05	2.65	12
6.4250	0.9519	4.5713	23.10	458.82	2.59	14
6.4290	0.9525	4.5792	23.30	458.39	2.50	15
6.4330	0.9529	4.5857	23.50	458.22	2.45	16
6.4370	0.9532	4.5927	23.70	458.96	2.61	17
6.4400	0.9538	4.6000	24.20	457.73	2.34	18
6.4430	0.9544	4.6400	25.00	457.68	2.33	19
6.4440	0.9546	4.6430	25.05	457.23	2.27	20
6.4445	0.9547	4.6440	25.10	457.12	2.21	21
6.4430	0.9548	4.6000	24.20	457.00	2.18	22
6.4430	0.9549	4.6000	24.20	457.08	2.20	23
6.4415	0.9555	4.6200	24.60	457.12	2.21	24
6.4440	0.9555	4.6250	24.60	457.29	2.23	25
6.4420	0.9555	4.6230	24.60	457.03	2.22	26

\* Original.

TABLE XLII.—*Alloy PP. Cast in Sand.*

	Per Cent.
Carbon . . . . .	3·79
Silicon . . . . .	2·96
Manganese . . . . .	0·25
Sulphur . . . . .	0·010
Phosphorus . . . . .	0·012

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Growth per Cent.	Weight. Grams.	Increase per Cent.	Heat No.
*6·0120	0·8793	3·6504	...	437·62	...	...
6·0670	0·8906	3·7790	3·54	438·19	0·12	1
6·0830	0·8941	3·8189	4·62	438·89	0·27	2
6·1140	0·8988	3·8807	6·32	439·78	0·41	3
6·1440	0·9040	3·9432	8·00	440·98	0·76	4
6·1760	0·9093	4·0100	11·65	441·96	1·00	5
6·2130	0·9150	4·0750	15·80	443·32	1·32	6
6·2780	0·9250	4·2188	18·80	445·55	1·82	7
6·3320	0·9333	4·3361	22·60	447·50	2·26	8
6·3950	0·9419	4·4547	23·50	449·78	2·77	9
6·4130	0·9445	4·5019	26·50	450·64	2·99	10
6·4700	0·9533	4·6176	27·60	453·08	3·65	12
6·5070	0·9590	4·7000	29·50	454·55	3·87	14
6·5250	0·9613	4·7341	30·40	454·95	3·95	15
6·5370	0·9630	4·7608	31·20	455·31	4·05	16
6·5510	0·9652	4·7920	32·20	455·49	4·10	17
6·5670	0·9667	4·8250	32·50	455·79	4·15	18
6·5760	0·9671	4·8350	32·75	455·89	4·18	19
6·5790	0·9689	4·8530	33·50	456·08	4·31	20
6·5840	0·9694	4·8750	33·75	455·87	4·18	21
6·5900	0·9700	4·8800	34·00	455·91	4·25	22
6·5970	0·9705	4·8900	34·30	455·77	4·12	23
6·5980	0·9716	4·9000	34·32	455·71	4·14	24
6·5980	0·9716	4·9000	34·32	455·53	4·03	25
6·5970	0·9730	4·9050	34·40	455·21	4·03	26
6·5970	0·9720	4·9020	34·36	455·13	4·00	27

\* Original.

TABLE XLIII.--*Alloy QQ. Cast in Sand.*

	Per Cent.
Carbon . . . . .	3.76
Silicon . . . . .	4.20
Manganese . . . . .	0.27
Sulphur . . . . .	0.010
Phosphorus . . . . .	0.012

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*5.9977	0.8942	3.7665	...	439.14	...	...
6.0120	0.8986	3.8122	1.22	439.60	0.10	1
6.0180	0.9011	3.8370	1.88	440.01	0.19	2
6.0240	0.9048	3.8728	2.84	440.57	0.26	3
6.0380	0.9112	3.9367	4.55	441.49	0.50	4
6.0500	0.9161	3.9909	5.98	442.26	0.71	5
6.0920	0.9228	4.0637	7.92	443.37	0.96	6
6.1210	0.9295	4.1530	10.30	444.44	1.21	7
6.1470	0.9355	4.2248	12.20	445.61	1.48	8
6.1650	0.9397	4.2754	13.50	446.49	1.67	9
6.1740	0.9424	4.3067	14.38	447.22	1.84	10
6.2400	0.9514	4.4353	17.80	449.18	2.28	12
6.3020	0.9643	4.6017	22.20	451.43	2.80	14
6.3330	0.9725	4.7035	25.00	452.70	3.08	15
6.3680	0.9799	4.8008	27.46	454.03	3.39	16
6.4050	0.9871	4.9011	30.10	455.60	3.75	17
...	...	...	...	457.68	4.22	18
...	...	...	...	460.03	4.75	19
...	...	...	...	461.36	5.08	20
...	...	...	...	462.49	5.30	21
...	...	...	...	463.44	5.53	22
...	...	...	...	464.24	5.73	23
...	...	...	...	464.72	5.90	24
...	...	...	...	465.44	6.00	25
...	...	...	...	465.54	6.01	26
...	...	...	...	465.60	6.02	27
...	...	...	...	465.69	6.03	28
...	...	...	...	465.98	6.11	30
...	...	...	...	466.19	6.18	31
...	...	...	...	467.35	6.44	33
...	...	...	...	467.91	6.57	34
...	...	...	...	471.18	7.30	37
...	...	...	...	473.08	7.75	40
...	...	...	...	474.84	8.15	42
...	...	...	...	476.09	8.41	44
...	...	...	...	477.48	8.70	46
...	...	...	...	477.84	8.85	47
...	...	...	...	478.74	9.05	49
6.70	1.005	5.32	41.6	480.25	9.33	52

\* Original.



TABLE XLIV.—*Alloy RR. Cast in Sand.*

	Per Cent.
Carbon . . . . .	3.79
Silicon . . . . .	4.83
Manganese . . . . .	0.30
Sulphur . . . . .	0.010
Phosphorus . . . . .	0.012

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Growth per Cent.	Weight. Grams.	Increase per Cent.	Heat No.
*5.9880	0.8832	3.6737	...	432.70	...	...
6.0090	0.8880	3.7213	1.30	433.36	0.15	1
6.0170	0.8909	3.7503	2.08	433.98	0.29	2
6.0200	0.8956	3.8519	4.82	434.00	0.32	3
6.0350	0.9064	3.8931	5.98	436.34	0.84	4
6.0470	0.9142	3.9686	8.10	437.43	1.09	5
6.0690	0.9222	4.0528	10.35	438.84	1.43	6
6.0910	0.9302	4.1382	12.62	439.96	1.68	7
6.1100	0.9362	4.2049	14.49	441.08	1.94	8
6.1260	0.9400	4.2508	15.70	441.94	2.14	9
6.1470	0.9431	4.2936	16.90	442.68	2.32	10
6.1900	0.9536	4.4202	20.35	444.54	3.10	12
6.2500	0.9646	4.5662	24.40	446.65	3.24	14
6.2800	0.9709	4.6488	26.50	447.81	3.50	15
6.3120	0.9734	4.6862	27.50	448.99	3.78	16
6.3490	0.9823	4.8106	30.90	450.41	4.41	17
6.4070	0.9956	5.0000	36.40	452.37	4.59	18
...	...	...	...	454.55	5.06	19
...	...	...	...	456.31	5.49	20
...	...	...	...	457.51	5.72	21
...	...	...	...	458.93	6.09	22
...	...	...	...	459.76	6.29	23
...	...	...	...	460.57	6.45	24
...	...	...	...	461.18	6.60	25
...	...	...	...	461.42	6.69	26
...	...	...	...	461.71	6.72	27
...	...	...	...	462.05	6.80	28
...	...	...	...	462.78	6.95	30
...	...	...	...	463.34	7.20	31
...	...	...	...	464.93	7.48	33
...	...	...	...	465.65	7.60	34
...	...	...	...	468.77	8.36	37
...	...	...	...	470.41	8.74	40
...	...	...	...	472.10	9.16	42
...	...	...	...	472.96	9.30	44
...	...	...	...	474.20	9.59	46
...	...	...	...	474.85	9.75	47
...	...	...	...	475.88	9.99	49
6.69	1.044	5.70	55.3	477.37	10.30	52

\* Original.

TABLE XLV.—*Alloy SS. Cast in Sand.*

	Per Cent.
Carbon . . . . .	3.38
Silicon . . . . .	6.14
Manganese . . . . .	0.30
Sulphur . . . . .	0.010
Phosphorus . . . . .	0.013

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Growth per Cent.	Weight. Grams.	Increase per Cent.	Heat No.
*6.0055	0.8887	3.7162	...	432.97	...	...
6.0090	0.8955	3.7844	1.84	433.76	0.18	1
6.0165	0.8992	3.8204	2.80	434.46	0.34	2
6.0210	0.9048	3.8709	4.20	435.44	0.57	3
6.0230	0.9105	3.9242	6.30	436.38	0.78	4
6.0320	0.9126	3.9449	6.38	438.75	0.87	5
6.0370	0.9173	3.9892	7.66	437.40	1.03	6
6.0490	0.9373	4.1731	12.38	439.45	1.50	7
6.0670	0.9512	4.3106	16.10	441.03	1.86	8
6.1020	0.9664	4.4745	20.45	442.85	2.28	9
6.1050	0.9700	4.5109	21.50	443.65	2.47	10
6.1490	0.9808	4.6443	22.30	445.11	2.80	12
6.1750	0.9876	4.7294	27.30	446.30	3.07	14
6.1930	0.9905	4.7210	28.40	446.79	3.21	15
6.2120	0.9939	4.8180	29.70	447.40	3.34	16
6.2310	0.9966	4.8595	30.70	448.24	3.50	17
...	...	...	...	449.40	3.80	18
...	...	...	...	450.91	4.15	19
...	...	...	...	452.01	4.42	20
...	...	...	...	453.01	4.64	21
...	...	...	...	454.14	4.87	22
...	...	...	...	455.29	5.15	23
...	...	...	...	456.20	5.38	24
...	...	...	...	458.13	5.82	25
...	...	...	...	459.62	6.18	26
...	...	...	...	460.68	6.41	27
...	...	...	...	461.71	6.65	28
...	...	...	...	463.47	7.04	30
...	...	...	...	464.40	7.26	31
...	...	...	...	467.11	7.72	33
...	...	...	...	467.79	8.05	34
...	...	...	...	470.91	8.78	37
...	...	...	...	473.80	9.42	40
...	...	...	...	476.05	9.90	42
...	...	...	...	477.82	10.30	44
...	...	...	...	479.09	10.60	46
...	...	...	...	479.74	10.82	47
...	...	...	...	480.99	11.10	49
...	...	5.98	61	483.12	11.55	52

\* Original.

Complete data of the growths of members of this series are given in Tables XL. to XLV., and the results are plotted in Fig. 3, Plate IV., so as to enable a comparison with the single-lettered series to be made. Photographs of the specimens are shown in the lower half of Plate II. The following table enables a comparison of the ultimate growths of the two series to be made with each other and also with the percentages of silicon they contain, and the results are also shown graphically in Fig. 2, p. 78.

TABLE XLVI.

Percentage Silicon.	Percentage Growth on Heating.			
1.07	N	15.40	NN	16.80
1.79	O	23.46	OO	24.60
2.96	P	32.85	PP	34.40
4.20	Q	43.9	QQ	41.6
4.83	R	59.5	RR	55.3
6.14	S	63	SS	61

Although, as has been mentioned, the double-lettered series grew more slowly than the previous one, the final results are not only of the same order of magnitude, but on the whole in good agreement, particularly in the case of the first three members where greater accuracy of measurement was possible. From the two series of tests the authors draw the following conclusions:—

1. In a series of cast irons of approximately constant carbon the ultimate growth after repeated heatings is, broadly speaking, proportional to the silicon present. This relationship holds up to 6 per cent. of silicon.

2. The growth is far in excess of that which can be caused by the conversion of combined to free carbon, and is in fact much the largest in high silicon alloys which contain no carbon combined with iron. (Alloys Q, R, and S.)

3. The behaviour of the alloys on repeated heating, and particularly of Q, R, and S, points to the view that two agencies are at work in their growth, viz.:—

- (a) The internal pressure of gas which they contain in their

original cast condition, and which is probably chiefly physical in its character.

(b) The effect of external gases in contact with the alloys during their heat treatment, and which is probably partly physical and partly chemical in its nature.

As regards 3 (b) considerable light has been thrown on the matter by a consideration of the changes of weight which accompany the changes of volume discussed above.

### THE INCREASE IN WEIGHT ACCOMPANYING THE GROWTH OF THE ALLOYS.

#### SERIES N TO S.

Full data are given in Tables XXXIV. to XXXIX. of the actual and the percentage increase in weight of these six alloys. The results are plotted in Fig. 2, Plate III., with the percentage increase in weight and the number of heats as co-ordinates.

The general resemblance to curves showing the increase in volume is at once obvious. Alloys N, O, and P increase in weight rapidly up to about the tenth heat, after which they decrease somewhat and reach a nearly constant weight in about twenty-six heats. Alloys Q and R increase in weight rapidly up to the fifteenth heat, after which the rate is diminished up to the thirtieth heat. They then increase at an accelerated rate up to the fifty-second heat. Just as in the case of the increase in volume Q and R increase in weight more slowly than P up to the eleventh and ninth heat respectively. The increase in weight of S is throughout the largest of the series.

#### SERIES NN TO SS.

(See Tables XL. to XLV., and Fig. 4, Plate IV.)

This series increased in volume more slowly than the other. Its increase in weight was also less rapid. This is notably the case with QQ, RR, and SS, especially the last-named, where the rate of increase was almost uniform.

The following table enables a comparison to be made between the final increases in weight obtained in the two series:—

TABLE XLVII.

Percentage Silicon.	Percentage Increase in Weight.	
	After Twenty-six Heats.	
1·07	N 0·65	NN 0·94
1·79	O 1·89	OOO 2·22
2·96	P 3·62	PP 4·03
	After Fifty-two Heats.	
4·20	Q 9·59	QQ 9·33
4·83	R 10·25	RR 10·30
6·14	S 13·20	SS 11·55

It will be observed that the increase in weight follows the same order as the increase in silicon, just as did the increase in volume. There are, however, complications in this case which probably do not affect the volume changes and make it more difficult to interpret the "increase in weight" curves.

During the heating and cooling of the alloys two causes are at work, one of which tends to increase, the other to decrease, their weight. Later experiments showed that they absorb gases from the interior of the muffle, principally carbon dioxide, carbon monoxide, and nitrogen. The two first-named gases tend to oxidise the silicon and carbon in the alloys. The former process, of course, results in an increase, the latter in a decrease of weight. That these two processes actually take place was shown in the following way:—

*The Oxidation of Silicon.*—The fact that the increase in weight follows the same order as the increase in silicon at once establishes a presumption in favour of this, especially as this element is the only variable in the series apart from iron, which, of course, correspondingly decreases. Analyses of silicon were made from an average sample of each alloy, beginning with the original casting, and continuing until the specimen of maximum weight was reached. There is, unfortunately, so

far as the authors are aware, no thoroughly reliable chemical method of distinguishing between combined and dissolved *silicon* and *silica* in cast irons. They found, however, on analysing any one series of the six alloys, that a sample of the original casting dissolved completely in hydrochloric acid, and that the final precipitate of silica after ignition was quite flocculent and white. Proceeding through the series, there came a point at which hydrochloric acid failed to dissolve the entire sample, a microcrystalline grey residue being left. The final precipitate of silica was less flocculent, and had a greyish tinge. Proceeding further, the insoluble residue increased until in the fully grown sample it reached a maximum, and the final precipitate was neither white nor flocculent, but a grey microcrystalline mass occupying a relatively very small bulk. The authors interpret these results to indicate that in the original sample the silicon was unoxidised. It is doubtless present as iron silicide in solid solution in the remainder of the iron. This would dissolve completely in hydrochloric acid and give ultimately a white amorphous flocculent precipitate. The grey microcrystalline residue, insoluble in hydrochloric acid, is probably silica deposited from solid solution by the action of the oxides of carbon at the temperature of the experiments. Evidence of these microcrystalline particles was also obtained in the microscopic examination of the alloys.

*The Oxidation of Carbon.*—This was shown by the following analyses made on average samples:—

TABLE XLVIII.

Alloy.	Percentage Carbon in the Original Alloy.	Percentage Carbon after Twenty-five Heats.	Percentage Loss.
N	3.98	2.45	38.4
O	3.98	2.40	39.7
P	3.79	2.60	31.4
Q	3.76	2.77	26.3
R	3.79	3.25	14.3
S	3.38	3.44	nil

The loss is greatest in N and O, which is only to be expected,

as these contain the greatest amount of combined carbon—a more easily oxidised form than graphite. It diminishes with rising silicon until in S it is *nil*.

Accordingly the increase in weight of the alloys observed is the net result of these two processes working in opposite directions. It is obvious from the curves, however, that the oxidation of silicon takes place much more rapidly than that of carbon, particularly in the case of N, O, and P. It is, of course, the latter process which causes the drop in the curves after twelve heats. The absence of this latter process is clearly seen in SS. The results leave no doubt that, with the exception of S, the apparent increases in weight are less than the real. An approximation to the latter can be reached in the following way:—

The mean apparent increase after twenty-five heats is calculated. (It is not to be expected that the two series will give exactly corresponding increases throughout, since the distribution of the constituents in cast irons is not uniform.) To this is added the loss in carbon after the same number of heats. The following results are then obtained:—

TABLE XLIX.

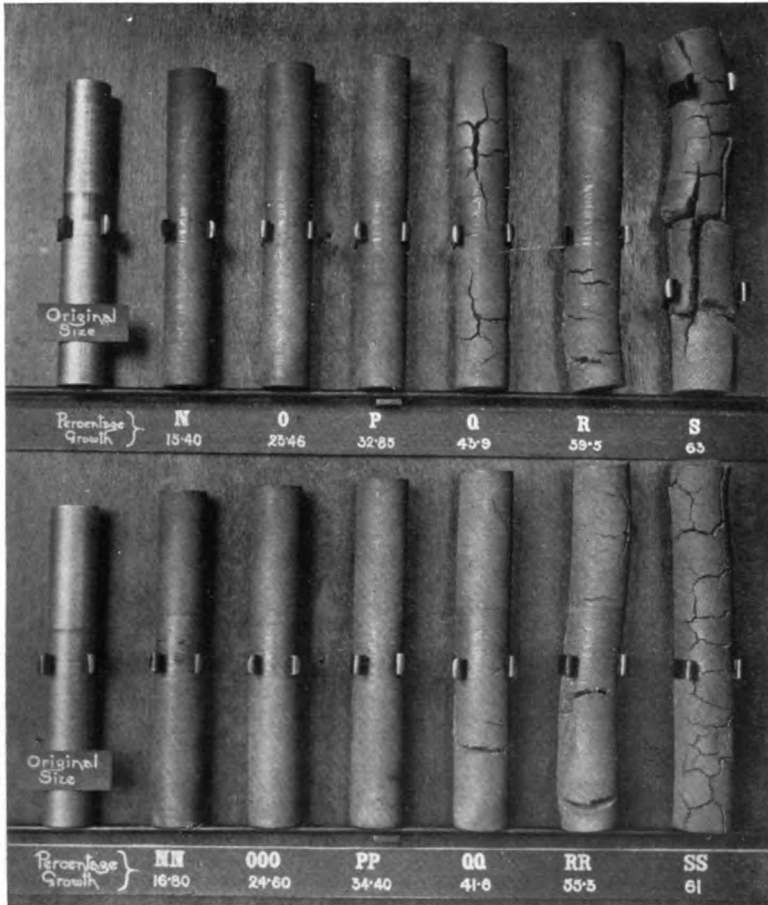
Alloy.	Mean Apparent Percentage Increase in Weight.	Percentage Loss of Carbon.	Approximate Percentage Gain in Weight.
N	0.85	1.53	2.38
O	2.07	1.58	3.65
P	3.85	1.19	5.04
Q	5.99	0.99	6.98
R	6.66	0.54	7.20
S	8.97	nil	8.97

If now the increase in weight consequent upon a complete oxidation of the iron silicide\* in the alloys to silica and iron be calculated, the following results are obtained, enabling a comparison to be made with the approximate increase just arrived at:—

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\* *Les Aciers Spéciaux*, 1904, pp. 79-100.

## PLATE II



Illustrating the Appearance of the Alloys of the N to S Series after they have reached their Ultimate Growth.





TABLE L.

Alloy.	Percentage Silicon.	Approximate Percentage Gain in Weight after Twenty-five Heats.	Calculated Gain on Assumption $\text{FeSi} \rightarrow \text{SiO}_2 + \text{Fe}$ .
N	1.07	2.38	1.22
O	1.79	3.65	2.04
P	2.96	5.04	3.37
Q	4.20	6.98	4.78
R	4.83	7.20	5.51
S	6.14	8.97	7.00

These figures show that something besides the silicon in the alloys is oxidised, even after only twenty-five heats, which tends to cause an increase in weight, and it is clear that this must be iron itself. Nothing else is present in sufficient quantity to account for the difference. The researches of Mr. Guillet \* indicate that the silicon in alloys of this type is present as iron silicide,  $\text{FeSi}$ , in solid solution. The most likely supposition, then, is that this compound is oxidised to a mixture of iron oxide and silica under the conditions of the experiments.

Even this, however, is insufficient to account for the whole of the increase in weight, as the following table shows:—

TABLE LI.

Alloy.	Percentage Silicon.	Approximate Percentage Gain in Weight.	Calculated Gain on the Assumption $\text{FeSi} \rightarrow \text{FeO} + \text{SiO}_2$ .
		After Twenty-five Heats.	
N	1.07	2.38	1.83
O	1.79	3.65	3.07
P	2.96	5.04	5.07
		After Fifty-two Heats.	
Q	4.20	10.45	7.20
R	4.83	10.81	8.28
S	6.14	12.38	10.42

\* *Les Aciers Spéciaux*, 1904, pp. 79-100.

It appears, therefore, that in addition there is some oxidation of the iron, uncombined with silicon, except possibly in the case of P. This deduction agrees with the fact that the fully grown alloys have very largely lost their metallic nature. They saw more like a piece of chalk than a piece of metal. Microscopic investigation also shows that their structure is revolutionised during growth.

The study of the changes of weight accompanying the growth of these alloys has thus shown:—

(a) A partial oxidation of carbon, which diminishes with increase of silicon and becomes *nil* at 6 per cent.

(b) A probably complete oxidation of the silicon, originally present as iron silicide, to a mixture of iron oxide and silica.

(c) A partial increase as iron uncombined with silicon. It is quite clear from a study of the curves of increase in volume and increase in weight that the two are closely related to one another, and that the growth of these alloys under heat treatment is bound up with a change in the chemical condition of the silicon and to some extent of the iron.

#### MICROSCOPIC STUDY OF THE ALLOYS.

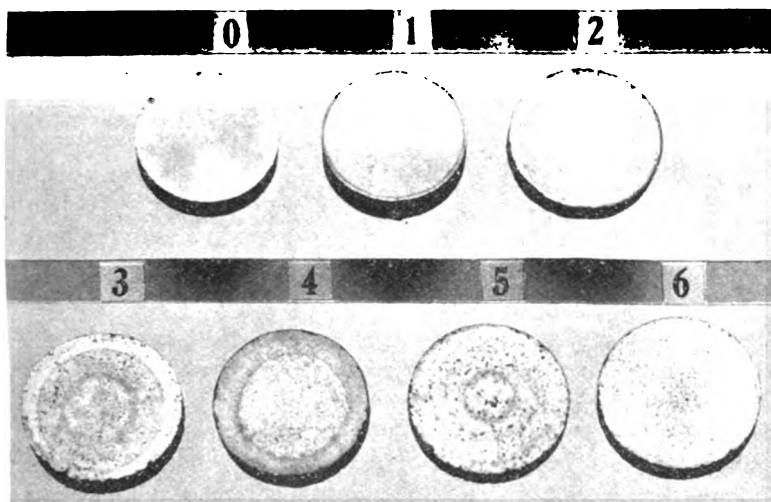
A very large number of specimens were investigated in this part of the research, and time did not permit of an exhaustive

TABLE LII.

Designation of Section.	The Number of Heats to which it was Exposed.
Alloy P {	Original Metal.
	1
	3
	6
	10
	15
	21

study of the changes of structure accompanying those of volume and weight in all cases. Alloy P was selected as being

the middle member of the series with about 3 per cent. of silicon. A number of sections, about 0.25 of an inch thick, were cut from the original bar and introduced into the muffle in which the main bars were being heated. From time to time as the heat progressed one of these was withdrawn, and in this way a series of sections was obtained at various stages



(0) Original casting. (1) After one heat. (2) After three heats. (3) After six heats. (4) After ten heats. (5) After fifteen heats. (6) After twenty-one heats.

FIG. 3.—Appearance of Etched Sections of Alloy P at various Stages of Growth, illustrating the Penetration of Gases and the Development of Holes.

of growth. The designation of these and the number of heats to which they correspond are contained in Table LII.

No. 0 corresponds to the original casting, No. 6 to the fully grown alloy, and the intervening numbers to the intermediate stages of growth. These specimens were first ground sufficiently to remove the oxidised layer, and were then polished and microscopically examined. No. 0 contained a few small holes. These increased somewhat in 1 and 2, the increase being mainly from the outside. In the remainder the holes were more uniformly distributed, but increased in number and size from No. 3 to No. 6.

The sections were then etched with 1 per cent. nitric acid in absolute alcohol. The surfaces of Nos. 0 and 1 dissolved quietly. In the case of No. 2 there was a slight evolution of gas, which became more marked in No. 3 and was very large in No. 4. This diminished in No. 5 and was still less in No. 6. These results show that as the heats progressed the alloy absorbed gas, which increased up to about the tenth heat, and after that diminished. The appearance of the etched surfaces at this stage is shown in Fig. 3, p. 99, which gives a most interesting idea of the way in which gases have penetrated into the alloy. (Natural size.)

No. 0 shows the etched surface of the original alloy. In No. 1 there is a thin dark ring at the edge. The authors interpret this to indicate the depth to which gases have penetrated after the first heat. This altered layer etches more readily than the rest of the alloys, as is only to be expected, hence the dark appearance. No. 2 (after three heats) shows a considerably deeper penetration of gas, which is, however, some distance from the centre, as is indicated by the concentric rings of various degrees of darkness. In No. 3 the gases appear to have reached the centre, and the dark rings are very marked. These diminish in Nos. 4 and 5, and are entirely absent from No. 6. This is no doubt owing to the fact that after twenty-one heats the chemical and physical effects of the penetrating gases are completed, and the material is as homogeneous as No. 0, and hence etches uniformly.

The sections were then examined at a magnification of 150 diameters, and typical structures photographed. (Plate V.)

No. 1 shows the structure of the original casting. As shown by the chemical analysis the greater part of the carbon is present as graphite (seen as black lines). The remainder of the field (mottled) shows the solid solution of iron silicide in the residue of the iron together with a small quantity of combined carbon.

No. 2 shows a boundary between a gas-penetrated area (dark) and a still unaffected part of the interior (light), in which the graphite plates and the solid solution are clearly seen.

No. 3 shows a completely gas-penetrated area in the early stages (after three heats).

No. 4 shows the structure of a part of the interior to which the gas has not yet penetrated after three heats. It is a most interesting photograph, because it throws light on changes that take place in the interior of the alloy before the gases penetrating from the outside have had time to make their influence felt. The three large black areas are holes, and the lines distributed through the white areas, although they doubtless correspond to original positions of graphite, no longer represent as much of it. They are for the most part *slits* from which the graphite plates have been removed. The agency in this removal appears to the authors to be the gas originally dissolved in the metal, which is probably liberated by heating at the surface of the solid solution in contact with the graphite. The latter is much the weakest mechanical constituent, and it appears to be forced into holes originally present in the casting, which may be, and doubtless are, enlarged by the breaking down of the boundaries between two holes, when these also consist of graphite. This point is dealt with more fully in connection with the tentative explanation given of the growth of the alloys (pp. 123-125).

No. 5 is typical of the structure of the alloy after maximum growth has been reached. It bears a distinct resemblance to No. 1 in general character, with one important difference, viz. that graphite has vanished from its original position in the form of plates, and the sharp black lines are replaced by blurred markings. The authors feel no doubt that these represent areas oxidised by the incoming gases at the temperature of the muffle which pass along the slits caused by the removal of graphite under the influence of the pressure of the originally dissolved gases (as outlined in the previous paragraph). Although large holes are numerous in the fully grown alloy, a field free from holes was selected to illustrate the final structure, as it enables the resemblance and the contrast to the original alloy to be most readily seen.

At this stage of the research it had become abundantly clear that the influence of gases on the growth of the alloys must be closely studied, but one question still remained to be answered before this was undertaken. Although graphite, or

temper carbon, had been shown to be present in all the alloys that grew on heating, yet in the nearly constant graphite series, N to S, the growth had been found to be roughly proportional to the silicon present. The question then arose, "Would an iron-silicon series containing no graphite grow on repeated heating?"

To settle this question three alloys with ascending silicon and as little carbon as possible were cast under similar conditions to previous alloys. Their analysis gave the following results :—

### IRON-SILICON SERIES.

TABLE LIII.

Mark.	Percentage.				
	Silicon.	Carbon.	Manganese.	Sulphur.	Phosphorus.
T	0.65	0.17	0.17	0.045	0.017
U	1.10	0.18	0.19	0.049	0.022
V	2.71	0.19	0.20	0.051	0.033

Microscopic examination showed in all three cases a solid solution (of iron silicide in iron). There were no traces of graphite or any other structural constituent present.

Machined bars were heated fifteen times under the same conditions as previous alloys. Full details of the changes of volume and weight are given in Tables LV. to LVII. A summary of the final values is contained in the table below.

TABLE LIV.

Alloy.	Percentage Silicon.	Percentage Change of Volume after Fifteen Heats.	Percentage Change of Weight after Fifteen Heats.
T	0.65	-0.025	-0.04
U	1.10	0.000	-0.03
V	2.71	+0.394	-0.02

Alloy T expanded slightly after the first heat, remained con-

stant after the next three, and then contracted slightly. There was also a slight progressive diminution in weight. Alloy U expanded very slightly after the first heat, returned to its original volume after the second heat, and then remained steady. The diminution in weight was very similar to that of T. Alloy V, after five heats, had still its original volume, and then began to grow very slightly, but even after fifteen heats the growth was only 0.394 per cent. It decreased in weight the least of the three alloys.

Thus it will be seen that the only alloy of the three which showed any tendency to grow was V, with 2.71 per cent. of silicon. The expansion was, however, very slight, and compared with that of P (2.96 per cent. silicon and 3.79 per cent. carbon), after the same number of heats was almost negligible (0.394 as compared with the mean figure of P and PP, 31.35 per cent.).

TABLE LV.—Alloy T. Cast in Sand.

	Per Cent.
Carbon . . . . .	0.170
Silicon . . . . .	0.650
Manganese . . . . .	0.170
Sulphur . . . . .	0.045
Phosphorus . . . . .	0.017

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*6.0000	0.9249	4.0300	...	507.250	...	...
6.0010	0.9249	4.0310	+0.017	507.230	-0.00	1
6.0010	0.9249	4.0310	+0.017	507.220	-0.00	2
6.0010	0.9249	4.0310	+0.017	507.190	-0.01	3
6.0010	0.9249	4.0310	+0.017	507.170	-0.01	4
6.0005	0.9249	4.0305	+0.012	507.130	-0.02	5
6.0000	0.9249	4.0300	0	507.110	-0.02	6
6.0000	0.9249	4.0300	0	507.090	-0.03	7
6.0000	0.9249	4.0300	0	507.060	-0.03	8
5.9990	0.9249	4.0290	-0.025	507.065	-0.03	9
5.9990	0.9249	4.0290	-0.025	507.050	-0.04	10
5.9990	0.9249	4.0290	-0.025	507.040	-0.04	12
5.9990	0.9249	4.0290	-0.025	507.040	-0.04	15

Alloys K, N, and P correspond closely to alloys T, U, and V in silicon content. They also contain about 3.9 per cent. of carbon, mostly in the form of graphite, as compared with a

\* Original.



mean figure of 0.18 per cent. of carbon, none of which is present as graphite, in the other series. A comparison can

TABLE LVI.—*Alloy U. Cast in Sand.*

						Per Cent.
Carbon . . . . .						0.180
Silicon . . . . .						1.100
Manganese . . . . .						0.190
Sulphur . . . . .						0.049
Phosphorus . . . . .						0.022
Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*5.9920	0.9230	4.0092	...	505.61	...	...
5.9925	0.9230	4.0095	+0.0083	505.59	-0.00	1
5.9920	0.9230	4.0092	0	505.59	-0.00	2
5.9920	0.9230	4.0092	0	505.55	-0.01	3
5.9920	0.9230	4.0092	0	505.52	-0.01	4
5.9920	0.9230	4.0092	0	505.47	-0.02	5
5.9920	0.9230	4.0092	0	505.46	-0.03	6
5.9920	0.9230	4.0092	0	505.44	-0.03	7
5.9920	0.9230	4.0092	0	505.42	-0.03	8
5.9920	0.9230	4.0092	0	505.42	-0.03	9
5.9920	0.9230	4.0092	0	505.40	-0.04	10
5.9920	0.9230	4.0092	0	505.40	-0.04	12
5.9920	0.9230	4.0092	0	505.44	-0.03	15

TABLE LVII.—*Alloy V. Cast in Sand.*

						Per Cent.
Carbon . . . . .						0.190
Silicon . . . . .						2.710
Manganese . . . . .						0.200
Sulphur . . . . .						0.051
Phosphorus . . . . .						0.033
Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*5.9985	0.9240	4.0200	1	502.51	...	...
5.9985	0.9240	4.0200	0	502.47	-0.01	1
5.9980	0.9240	4.02165	+0.042	502.47	-0.01	2
5.9980	0.9240	4.02165	+0.042	502.45	-0.01	3
5.9985	0.9240	4.0200	0	502.43	-0.01	4
5.9985	0.9240	4.0200	0	502.40	-0.02	5
5.9995	0.9240	4.0260	+0.067	502.39	-0.02	6
6.0000	0.9245	4.0278	+0.194	502.38	-0.02	7
6.0010	0.9248	4.0300	+0.248	502.37	-0.03	8
6.0010	0.9.48	4.0300	+0.248	502.37	-0.03	9
6.0010	0.9252	4.0344	+0.358	502.35	-0.03	10
6.0020	0.9252	4.0350	+0.375	502.39	-0.02	12
6.0030	0.9252	4.0358	+0.394	502.42	-0.02	15

\* Original.

thus be made between the changes of volume of the two series under similar tests after fifteen heats by means of

TABLE LVIII.

Alloy.	Carbon.	Silicon.	Percentage Change of Volume.	Alloy.	Carbon.	Silicon.	Percentage Change of Volume.
T	0.17	0.65	-0.025	K	3.90	0.69	+5.40
U	0.18	1.10	0.000	N	3.98	1.07	+15.20
V	0.19	2.71	+0.394	P	3.79	2.96	+31.35

This comparison serves to emphasise anew that free carbon, in the form either of graphite or temper carbon, is one of the essential factors in the growth of cast irons under heat treatment (*cf.* pp. 71-72). The previous series of alloys, however (N to S), brought out equally clearly the fact that in a constant graphite series the growth is roughly proportional to the silicon present. It is clear, therefore, that both graphite and silicon are involved in these changes of volume after repeated heatings.

#### INVESTIGATION OF THE INFLUENCE OF GASES ON THE GROWTH OF CAST IRONS.

A sketch of the apparatus used is shown in Fig. 4. It consisted of a glazed Berlin porcelain tube (A), which, as our tests showed, would hold a vacuum for many hours at 900° C., when heated by gas, without any leakage. The ends were closed with rubber stoppers especially purified for the purpose. On the left-hand side of the tube (see diagram) a stopcock was inserted through the stopper, and served to introduce air into the apparatus when required. The specimen (B) to be tested was introduced through this end and placed in the position shown. An arrangement for water-cooling the ends of the tube in contact with the stoppers was also used. The other end of the tube communicated with a

mercury gauge (C) and a gas pipette of known volume (D), and thence to a Fleuss pump.

In this apparatus specimens could be heated for required periods at a desired temperature. The volume of gas evolved could be calculated at any moment from the total volume of

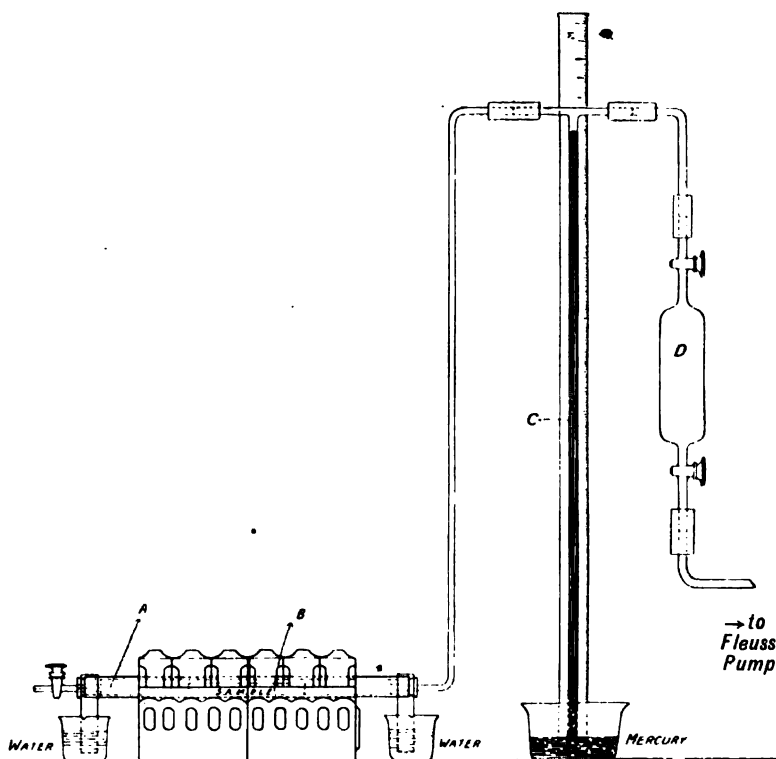


FIG. 4.—Apparatus used for Investigating the Influence of Gases on the Growth of Cast Irons.

the apparatus, which had been previously determined, and the pressure. By closing the two stopcocks of the gas pipette, and transferring the gas to a gas-analysis apparatus, the composition could be determined.

The dimensions of the porcelain tube were 24 inches by  $\frac{3}{4}$  inch. Sufficient of this was heated so that a 6-inch speci-

men of alloy, placed in the centre of the tube, was at approximately the same temperature throughout its length. The same period of heating, viz. four hours, was allowed as in the gas-heated muffle experiments. It was found that after sixteen to twenty such repetitions the tube began to leak at  $900^{\circ}\text{C}$ ., even though it held a vacuum perfectly in the cold and there were no signs of cracking of the glaze. Directly this was noticed the tube was discarded and a fresh one used. The specimens of alloy for test were machined to 6 inches by  $\frac{1}{2}$  inch.

### EXPERIMENTS WITH S.

This alloy was chosen because it had shown the maximum growth of the N to S series, viz. about 62 per cent., and a 6-inch length was machined as close as possible to the gate of the casting, in order to secure a piece comparable with the original specimen of S, which cracked so quickly on heating in a muffle (*cf.* p. 76). This specimen is designated  $S^{\dagger}$ . Its exact volume was 19.88 cubic centimetres.

This specimen was heated in the evacuated apparatus, the temperature being raised gradually. Gas was given off readily (the exact temperature was not measured). After two heats the bar was measured and weighed and its appearance noted.

TABLE LIX.—*Alloy  $S^{\dagger}$ , Heated in Vacuo at  $900^{\circ}\text{C}$ .*

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Change per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*6.0250	0.5227	1.2928	...	144.816	...	...
6.0167	0.5234	1.2943	+0.120	144.821	+0.003	2
6.0157	0.5234	1.2941	+0.101	144.820	+0.003	5
6.0145	0.5233	1.2924	-0.04	...	...	11
6.0145	0.5233	1.2924	-0.04	144.828	+0.008	16

(Table LIX. gives the exact data.) A slight growth was found (0.12 per cent.), and a minute increase in weight (0.003 per cent.). 12.4 cubic centimetres of gas had been evolved at

\* Original.

this stage. It was observed that the surface of the bar was slightly discoloured (greenish yellow to blue), and that this was more marked at the gate end. The authors interpret this as indicating that the gas which was evolved from the metal from about  $800^{\circ}$  C. upwards reacted with it, causing the discoloration, and that the effect was more marked at the gate end because more gas was present. After the fifth heat the bar had begun to shrink, but was still a little larger than the original size. After the eleventh heat it had shrunk further, and was 0.04 per cent. smaller than the original. This value was not altered after sixteen heats. The evolution of gas continued over eight heats, that is a total of thirty-two hours, and reached a total of 22.20 cubic centimetres. The bar therefore gave up 1.11 times its own volume of gas. Plate VI. shows its appearance after constant volume was reached.

It was not possible in this experiment to determine the average composition of the gas evolved from the alloy on heating, since the apparatus had to be disconnected from time to time to enable the bar to be measured and weighed. The determination was, however, made on another sample cut somewhat farther from the gate, and it was noticed that much less gas was given off. Its composition was as follows:—

Constituent.	Percentage by Volume.
Carbon dioxide . . . . .	nil
Carbon monoxide . . . . .	nil
Oxygen . . . . .	nil
Hydrogen . . . . .	87.5
Nitrogen . . . . .	12.5

Thus the only constituents were hydrogen and nitrogen, present in the proportion of 7 to 1 by volume. This result agrees with that obtained by Troost and Hautefeuille, who found that hydrogen was the principal gaseous constituent of cast irons.

During the sixty-four hours' heating the bar gained 12 milligrams in weight, corresponding to a percentage increase of 0.008. This increase is very small, and was probably caused by a very slight leak in the apparatus, which it is almost impossible to avoid when rubber stoppers have to be used.

The experiment thus showed that alloy S, when heated to  $900^{\circ}$  C. in vacuo, not only does not grow, but actually shrinks slightly. It is interesting to note that it contracted slightly in length, and expanded in width. This alloy grew 62 per cent. (mean value) when heated to constant volume in a muffle in contact with gases. There is, accordingly, no doubt but that the growth is caused by gases.

If the volume changes in Table LIX. are studied a further important conclusion can be drawn, viz. that the gas contained in the alloy cannot have any appreciable effect in causing the growth of this alloy, otherwise there would be a permanent growth in vacuo. The experiment has shown that it is possible to extract this gas without causing more than at most a slight temporary expansion. It is therefore clear that the external gases in the muffle are responsible for the 62 per cent. growth of S.

This deduction the authors proceeded to test experimentally, and they have been able to substantiate it conclusively in the following way: A fresh bar of alloy S was machined to about 6 inches by 0.5 of an inch. It was heated in vacuo at  $900^{\circ}$  C. until no more gas was given off, and afterwards in the muffle under the same conditions as the other bars. Full details of the volume and weight changes are given in Table LX., the bar being designated SS<sup>1</sup>.

This bar grew very slowly. After twenty-one heats the expansion was only 4.08 per cent., and after thirty only 9.7 per cent. Beyond this stage, however, it grew rapidly. After fifty-three heats the growth was 67.7 per cent., which is, in fact, slightly larger than the figures 63 and 61 obtained for S and SS respectively. After five more heats there was no further growth. It was thus shown that the growth of alloy S is due entirely to the agency of gases penetrating from the muffle.

There was, however, a most important difference between the final condition of SS and S on the one hand and SS<sup>1</sup> on the other. Whereas the two former cracked extensively during growth and became greatly deformed, the latter hardly cracked at all, and kept its cylindrical form almost perfectly. (Its appearance is seen in Plate VI.) The cracking of S and SS, therefore, is due to pressure from within caused by the dis-

solved gases hydrogen and nitrogen. (Their coefficient of expansion at the ordinary temperature is about 400 times

TABLE LX.—*Alloy SS<sup>†</sup>.*

First heated in vacuo at 900° C. to extract dissolved gases, and afterwards in the muffle furnace.

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Growth per Cent.	Weight. Grams.	Increase per Cent.	Heat No.
*6.0180	0.5271	1.313	...	146.879	...	...
6.0210	0.5278	1.318	0.380	146.936	0.04	2
6.0250	0.5288	1.320	0.765	147.041	0.11	6
6.0600	0.5328	1.350	2.82	147.542	0.45	12
6.0880	0.5365	1.373	4.08	...	...	21
6.0930	0.5371	1.380	5.12	148.020	0.78	22
6.1010	0.5374	1.388	5.73	148.112	0.84	23
6.1125	0.5390	1.395	6.25	148.266	0.94	24
6.1200	0.5390	1.400	6.64	148.361	1.01	25
6.1270	0.5398	1.405	7.02	148.462	1.08	26
6.1400	0.5410	1.420	8.19	148.608	1.18	27
6.1525	0.5423	1.425	8.59	148.784	1.31	28
6.1695	0.5442	1.435	9.29	149.000	1.45	29
6.1870	0.5455	1.440	9.70	149.180	1.58	30
6.2260	0.5491	1.480	12.95	149.660	1.90	32
6.3010	0.5563	1.535	17.95	150.490	2.46	35
6.4600	0.5703	1.679	28.00	151.433	3.11	37
6.5870	0.5828	1.760	33.75	152.363	3.73	39
6.6650	0.5892	1.815	38.30	153.244	4.34	41
6.8125	0.6053	1.960	49.40	154.532	5.21	43
6.9375	0.6150	2.060	57.00	156.440	6.55	45
7.0312	0.6194	2.118	61.30	160.490	9.30	46
7.1171	0.6270	2.140	63.00	162.333	10.50	48
7.1250	0.6288	2.212	67.70	165.245	12.50	53
7.1250	0.6288	2.212	†67.70	164.890	12.26	58

greater than that of grey cast iron.) And their rapid growth is due to the relatively large surface thus exposed to the penetration of the muffle gases.

At the conclusion of its growth SS<sup>†</sup> was again heated in vacuo and the evolved gas analysed. It had the following composition:—

Constituent.	Percentage by Volume.
Carbon dioxide . . . . .	33.00
Carbon monoxide . . . . .	14.54
Oxygen . . . . .	nil
Hydrogen . . . . .	42.50
Nitrogen . . . . .	9.96

\* Original.

† This figure constitutes a satisfactory check on the values obtained for S and SS, which cracked during heating, and whose growth could only be approximately estimated (pp. 85 and 91).

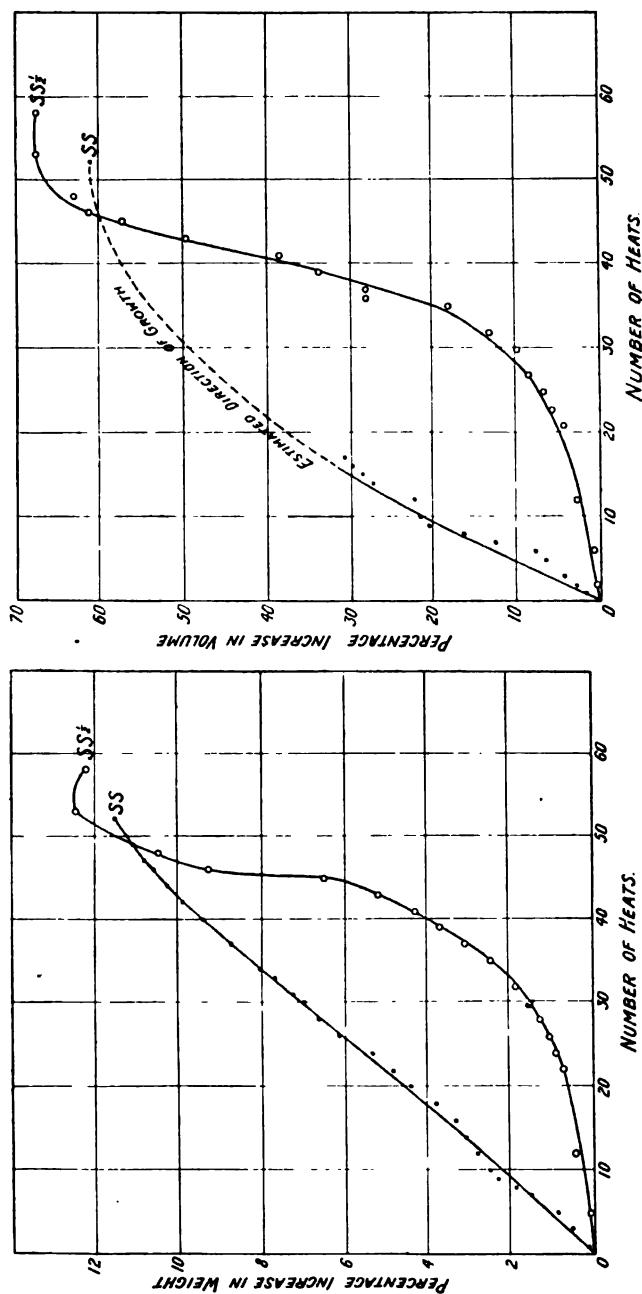


FIG. 5. — Illustrating the Difference between the Rates of Growth and Increase in Weight of SS (alloy heated in muffle without any preliminary treatment) and SSf (alloy heated in muffle after being heated in vacuo until no more gas was evolved).



showing that nearly half the total quantity of penetrating gases consists of oxides of carbon. They are responsible for the oxidation of the iron silicide, which is so closely bound up with the growth of the alloy (*cf.* pp. 97 and 98).

Fig. 5 enables the growth and the increase in weight of SS and SS<sup>1</sup> to be followed as the heats progressed. The curves emphasise anew the intimate connection between the increase in volume and weight, the similarity being very marked. They also bring out clearly the influence of gases originally present in the alloy on the rate of growth.

The proof just given that the growth of this alloy is caused entirely by the penetration of gases from the muffle is im-

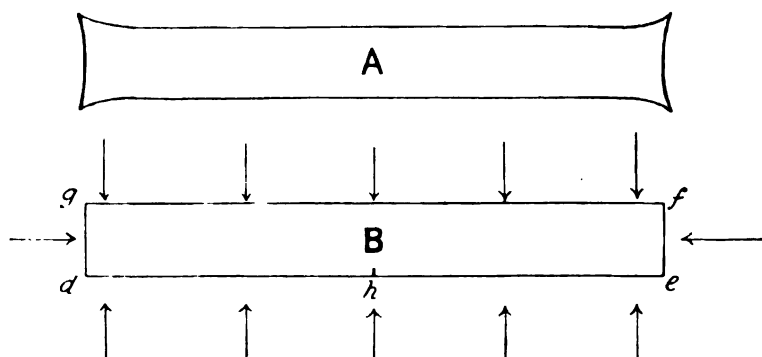
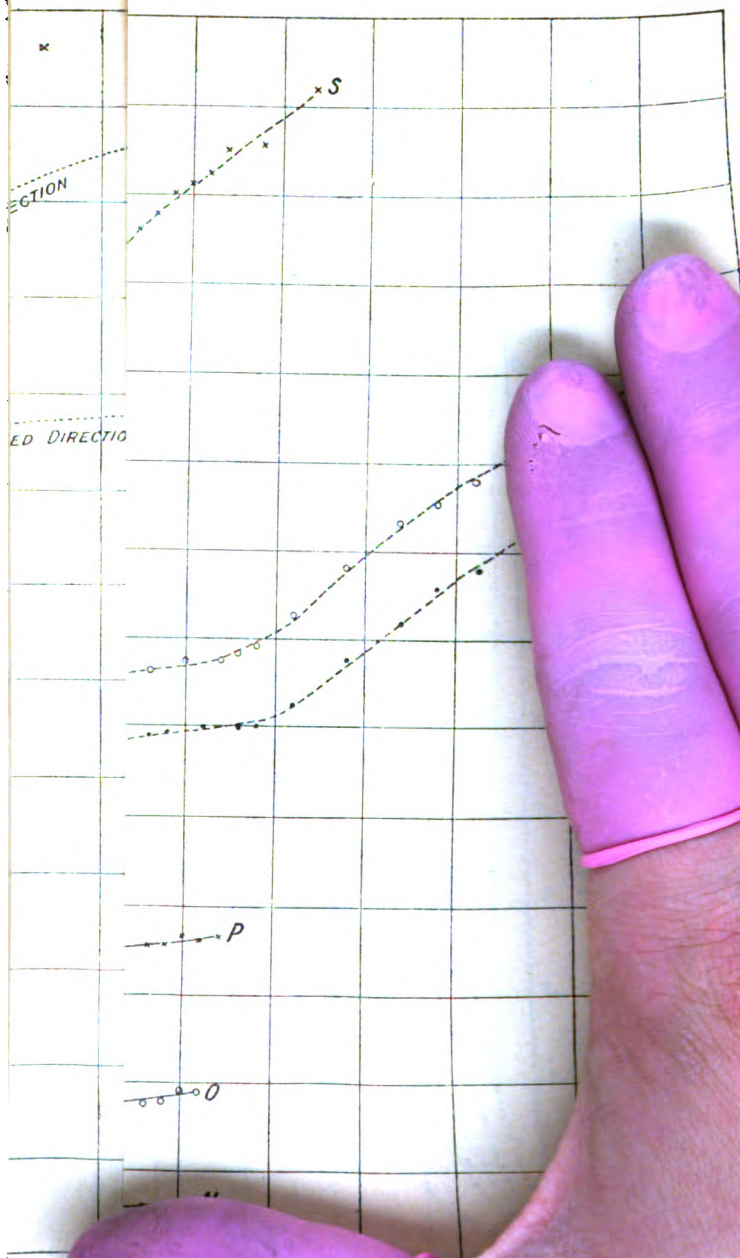


FIG. 6.

portant, because it explains the interesting fact noted on p. 76 that the corners not only of this alloy but also of Q and R grew more rapidly than the rest of the bar, giving rise to the following shape at a certain stage of growth (A), the ends being cupped.

Let B be the shape of the original cylindrical bar, and let the arrows indicate the penetration of gases on all sides. It is obvious that the corners of the bar *d*, *e*, *f*, *g* are subjected to gas penetration in two directions which are approximately at right angles to one another, whereas a point such as *h* is only acted on in one direction. Their growth is therefore more rapid at first (although the rest of the bar ultimately catches up).



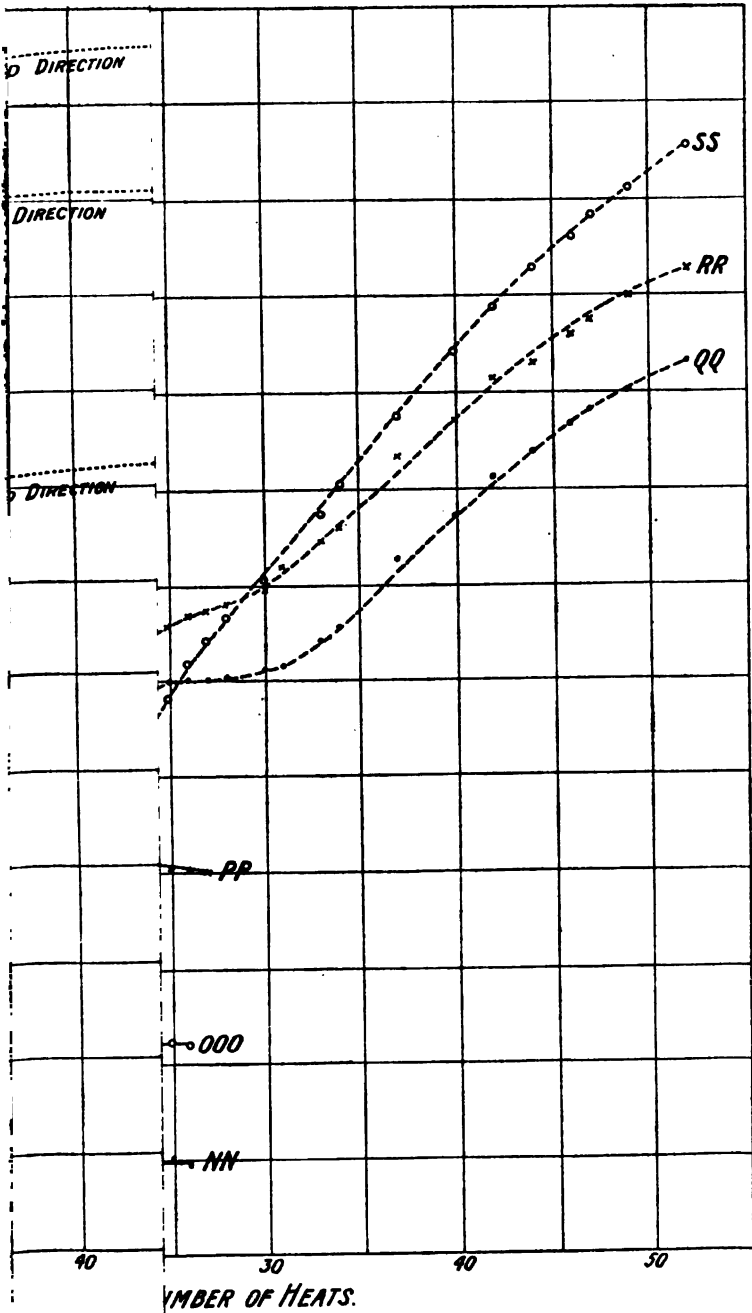
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D DIRECTION

DIRECTION

D DIRECTION



SS (see Tables X<sup>n</sup> Weight of Alloys NN to SS (see Tables XL. to XLV.).



## PLATE V

ILLUSTRATING THE STRUCTURAL CHANGES THAT ACCOMPANY  
THE GROWTH OF P CAUSED BY REPEATED HEATINGS.

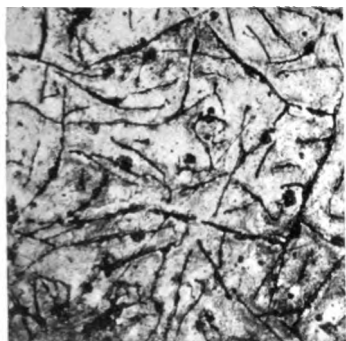


FIG. 1.—Structure of Original Casting.  
Black lines represent graphite plates.  
Magnified 150 diameters.

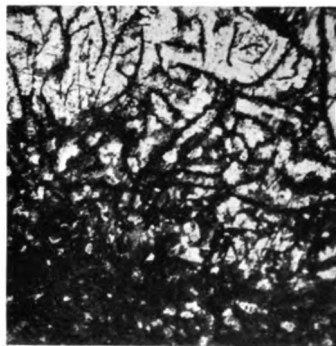


FIG. 2.—Boundary between Gas-penetrated  
Area (dark) and Unaffected Portion  
(light). Magnified 150 diameters.

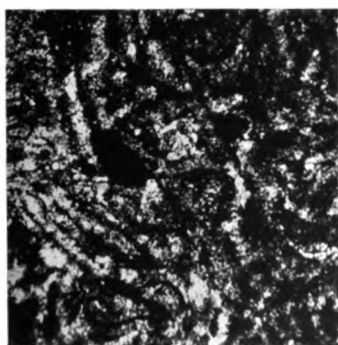


FIG. 3.—Gas-penetrated Area.  
Magnified 150 diameters.

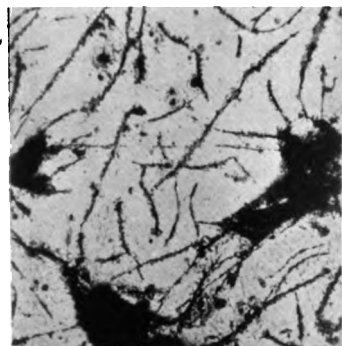


FIG. 4.—Shows Development of Holes  
in the Interior to which Gases have  
not yet penetrated. Magnified 150  
diameters.

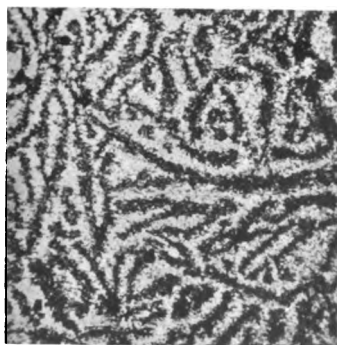


FIG. 5.—Typical Structure after Maxi-  
mum Growth has been reached.  
Magnified 150 diameters.



There can be no doubt that the more rapid growth of the end of the bar nearest the gate of the casting is connected with the fact that it contains more dissolved gas. But this does not of itself explain the more rapid growth, because the experiments in vacuo have shown that this gas can be removed on heating without causing any permanent growth. Although time has not permitted this question to be investigated, the authors think that the more rapid growth, which is usually accompanied by more or less cracking, may be caused by an explosive reaction between the penetrating oxides of carbon and the dissolved hydrogen in the alloy.

#### EXPERIMENTS WITH N.

This alloy was chosen because both in physical characteristics and in growth it presented the greatest contrast to S. It was a very close-grained iron; it had the greatest mechanical strength of the series, and it grew the least on heating. The results obtained with it, while apparently not so striking as those obtained with S, are in reality equally interesting and scientifically important.

A bar cut from the gate end of the casting was machined to the usual size, and is designated N<sup>1</sup>. This was heated in vacuo under similar conditions to S<sup>1</sup>. Gas was given off, but much less readily. After the first heat the bar was measured, and found to have increased 1.63 per cent. in volume, Table LXI., p. 114, gives the full data. It will be observed that the growth proceeded steadily up to twenty-five heats, when a maximum was reached, no further increase taking place after an additional ten heats. The ultimate growth was 11.1 per cent. (see Plate VII.).

After the first heat a loss in weight of 3 milligrams was found. Beyond this, however, a gain in weight took place of the same order of magnitude as with S (26 milligrams in thirty-five heats), and doubtless due to the same cause, viz. a minute leak through the stoppers.

The total volume of gas evolved was 23.27 cubic centimetres, the volume of the bar being 19.87 cubic centimetres. The bar thus gave up 1.17 times its volume of gas. Its com-



position determined on another sample obtained from a fresh bar was as follows:—

Constituent.	Percentage by Volume.
Carbon dioxide . . . . .	1·09
Carbon monoxide . . . . .	nil
Oxygen . . . . .	nil
Hydrogen . . . . .	98·54
Nitrogen . . . . .	0·37

The gas thus consisted almost entirely of hydrogen.

TABLE LXI.—*Alloy N<sup>1</sup>. Cast in Sand.*

Heated in Vacuo.

	Per Cent.
Carbon . . . . .	3·98
Silicon . . . . .	1·070
Manganese . . . . .	0·25
Sulphur . . . . .	0·010
Phosphorus . . . . .	0·013

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Growth per Cent.	Weight. Grams.	Change per Cent.	Heat No.
*5·9960	0·5214	1·2790	...	148·6215	...	...
6·0255	0·5243	1·3030	1·63	148·6175	-0·003	1
6·0520	0·5263	1·3169	2·96	148·6191	-0·002	3
6·0730	0·5284	1·3300	4·00	148·6200	-0·001	5
6·1180	0·5319	1·3600	6·34	148·6265	+0·003	11
6·1490	0·5346	1·3790	7·96	148·6320	+0·008	16
6·1800	0·5375	1·4040	9·80	148·6430	+0·015	20
6·2050	0·5401	1·4210	11·10	...	...	25
6·2048	0·5400	1·4209	11·10	148·6603	+0·026	35

TABLE LXII.—*Alloy NN<sup>1</sup>.*

First heated in vacuo at 900° C., and afterwards in a muffle furnace.

Length. Inches.	Diameter. Inch.	Volume. Cubic Inches.	Growth per Cent.	Weight. Grams.	Increase per Cent.	Heat No.
*6·0040	0·5331	1·330	...	154·00	...	...
6·0700	0·5396	1·390	4·50	155·66	1·07	2
6·1940	0·5495	1·460	9·80	156·79	1·82	6
6·2660	0·5548	1·500	12·70	156·66	1·08	17
6·2600	0·5550	1·510	13·50	156·13	1·33	21
6·2600	0·5553	1·514	14·00	156·13	1·39	22
6·2602	0·5548	1·513	13·90	156·39	1·56	23
6·2615	0·5552	1·513	13·90	156·56	1·66	24
6·2630	0·5548	1·510	13·50	156·79	1·82	25
6·2630	0·5548	1·510	13·50	156·88	1·87	26
6·2630	0·5548	1·510	13·50	156·73	1·77	27
6·2630	0·5548	1·510	13·50	156·73	1·77	28
6·2630	0·5548	1·510	13·50	156·72	1·76	29

\* Original.

The experiment thus showed that this alloy behaves quite differently from  $S^{\frac{1}{2}}$  when heated in vacuo, and that it grows to a very considerable extent, both absolutely and relatively to the total growth, when heated in a muffle.

In order to get an exact comparison another bar,  $NN^{\frac{1}{2}}$ , was heated in vacuo until no further gas was evolved, then transferred to a muffle and heated to ultimate growth under the

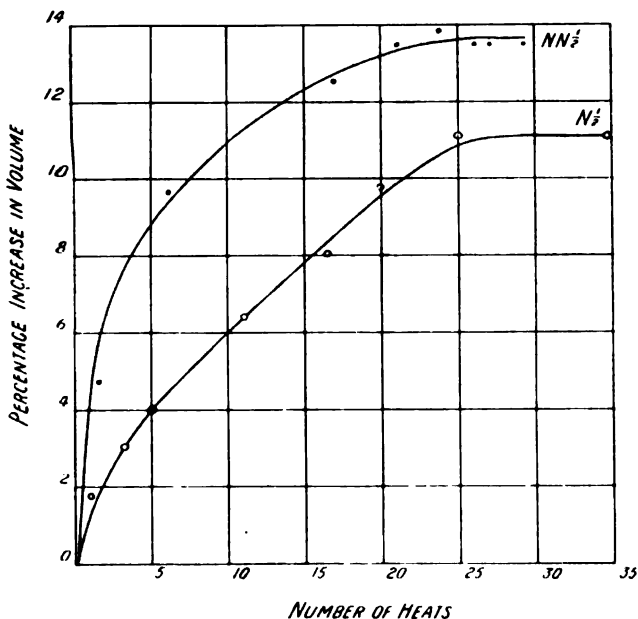


FIG. 7.—Showing Rate of Growth of N.  $NN^{\frac{1}{2}}$  heated in muffle to constant volume.  $N^{\frac{1}{2}}$  heated in vacuo to constant volume.

same conditions as  $SS^{\frac{1}{2}}$ . It grew very similarly to N and NN, although its ultimate growth was rather less, viz. 13.50 per cent. The growths of  $N^{\frac{1}{2}}$  and  $NN^{\frac{1}{2}}$  are plotted in Fig. 7. They are seen to be similar, although  $NN^{\frac{1}{2}}$  grew rather more rapidly, but the final difference between them was only 2.4 per cent., whereas between the corresponding  $S^{\frac{1}{2}}$  and  $SS^{\frac{1}{2}}$  it was 6.7.7 per cent.

The fully grown  $NN^{\frac{1}{2}}$  was finally heated in vacuo and the

evolved gas analysed. It proved to have the following composition:—

Constituent.	Percentage by Volume.
Carbon dioxide . . . . .	17·61
Carbon monoxide . . . . .	27·46
Oxygen . . . . .	0·35
Hydrogen . . . . .	40·14
Nitrogen . . . . .	14·44

As in the fully grown SS<sup>1</sup>, so here the gases which have penetrated into NN<sup>1</sup> consist of oxides of carbon to the extent of about 45 per cent.

Photographs of the fully grown N<sup>1</sup>, NN<sup>1</sup>, and the original alloy are given in Plate VII.

The behaviour of alloy N is thus in complete contrast to that of S, as is shown in the following table:—

Alloy.	Percentage Growth when Heated in Vacuo.	Percentage Growth, when Heated in Muffle Furnace after previously Extracting as much Gas as possible in Vacuo.
N	+11·10	+13·50
S	-0·04	+67·70

The most striking difference between the alloys is their behaviour when heated to constant volume in vacuo. S shrinks slightly, but remains almost constant, whereas N grows 11·1 per cent. How is this difference to be explained?

The authors suggest the following hypothesis: S is a very open-grained alloy, and it is quite intelligible that the gas it contains in its originally cast condition should be comparatively readily removed by heating in vacuo without causing a permanent growth. On the other hand N is a close-grained alloy. It is a compact aggregate of iron silicide (dissolved in iron) and graphite with very few holes, and it appears that the gas it contains is removed in vacuo with much greater difficulty. In fact the only explanation of the 11 per cent. growth in vacuo that the authors can suggest is that some of the gas is never removed at all, but remains permanently imprisoned in the alloy. If

this is the case, and if it is further assumed that the gas is liberated on heating, probably at the boundaries between the iron and graphite plates, then its enormously greater coefficient of expansion will cause an internal pressure which is sufficient to expand the metal permanently. In this way cavities are formed, and doubtless enlarged in places where the boundaries between two cavities consist of mechanically weak graphite.

(The expansion consequent upon a complete conversion of combined to free carbon in N has to be taken into consideration. But, as is calculated on p. 77, this cannot at the very outside be responsible for more than 1.58 out of a total of 11.1 per cent.)

N thus appears to furnish an instance of an alloy in which the dissolved gases are capable of causing a large growth, at any rate when external gases are removed.

On the other hand when N is caused to grow by heating in a muffle the curves of increase of volume and increase of weight leave no doubt that they are closely related. The greater part of the increase is effected in the first ten heats. It seems most probable, therefore, that under these conditions the growth is largely due to the penetrating gases. How much is due to the pressure of originally dissolved gases it is very difficult, if not impossible, to estimate. It was noticed, however, that the enlargement of the ends of bars N, O, and P in the early stages of growth was very much less marked than in Q, R, and S. Indeed it was barely perceptible in N and O. The explanation of this may be that the pressure of the dissolved gas is responsible for the more even growth in these cases in some way that is yet not understood.

Summarising these results, it may be said that there are alloys, *e.g.* S, whose growth in air is due entirely to oxidising gases penetrating their interior, and others, *e.g.* N, where this may not be the sole agent, but where originally dissolved gases contribute to some extent to the growth.

Time has not permitted of a completer study of this aspect of the growth of cast irons. Investigations are, however, still proceeding, and will, it is hoped, form the subject of a later paper.

COMPARISON WITH MR. OUTERBRIDGE'S  
RESULTS.

While the experimental results obtained by Mr. Outerbridge and the authors are usually in general agreement in places where the same ground is traversed, it seems probable that his views as to the cause of the "growth" of cast irons after repeated heatings will require to be modified in the light of results obtained in the foregoing research.

1. His statement (p. 31) that "the increase of free carbon does not account in any way for the enlargement of the bar" \* was doubtless true of the grey iron with which he was experimenting; and holds for grey irons generally. But it is not true of white irons which become grey on heating, and expand in so doing. So far as existing data permit of an opinion being formed, this change is quite enough to account for the whole of the growth observed. (Alloys A and M.) The authors' experimental results with these two alloys are in disagreement with his opinion that (p. 31) "white iron in which nearly all of the carbon is in the combined form does not expand sufficiently to overcome the original shrinkage even after all of the combined carbon has been changed to graphite;" and conclusively show that it does.

2. Mr. Outerbridge states (p. 31) that his "enlarged bar (40·98 per cent.) weighed precisely the same as before treatment." The authors have great difficulty in accepting this statement, which is at variance with their entire experience. His bar was heated in an iron pipe, the ends of which were stoppered with clay, at a temperature of 800° C.; that is, under conditions which permitted of the penetration of oxidising gases, and were thus very similar to those used by the authors. In not a single one of the numerous cases examined by them did the weight remain constant. Every grey iron increased in weight, and the

\* Mr. Outerbridge and the authors have used the word "shrinkage" in a somewhat different sense. There is no real disagreement between them. (See author's reply to correspondence.)

growth has been shown to be connected with this increase in the most intimate manner.

3. The authors' results have shown that Mr. Outerbridge's conclusion that "the astonishing change in volume is a molecular and not a chemical one, thus substantiating my original theory of the mobility of cast iron" (p. 32) is incorrect in this unqualified form. Their experiments connect in a very intimate way the growth of grey irons with a chemical change in the condition of the iron silicide which is invariably present.

4. His statement (p. 32) that "The peculiar property of cast iron of increasing in bulk under the influence of heat is inherent in the metal, and has existed for all time" is also incorrect in this unqualified form. Alloy S is an exception. Its growth has been proved to be due entirely to the action of penetrating gases.

#### SUMMARY.

The following section contains a summary of methods and results in the order in which they were obtained.

1. The conditions under which the maximum growth of commercial cast irons is brought about by repeated heatings were determined. As a result a period of four hours at 900° C. was chosen for the experiments.

2. It was shown that for growth to take place both heating and cooling are required. A given specimen grows no more under a seventeen hours' than a three hours' treatment (pp. 33 and 34).

3. Methods of measurement of temperature and volume changes were decided upon. For the former thermojunctions and a direct-reading pyrometer were used; for the latter micrometer callipers reading to 0.0001 of an inch (pp. 35 and 36).

4. Test bars were heated in a cast-iron muffle protected from the direct action of the flame by another muffle of fireclay.

5. Three commercial cast irons were investigated. They grew at different rates and to different extents. After ninety-four heats they reached a constant volume. The growths varied between 35.21 and 37.50 per cent. An increase in weight was found in all cases (pp. 36-43).

6. The first step consisted in an attempt to correlate growth with chemical composition.

7. *Iron-carbon Series of Alloys containing no Graphite.*—The carbon ranged between 4.03 and 0.15 per cent. Other constituents were low and constant. (Eight alloys, B to I, p. 44.)

A. *Sand Cast Alloys.*—White irons. The final result after thirty-nine to seventy-eight heats was a permanent shrinkage in all cases, which in six out of eight cases was not more than 0.5 per cent. A diminution in weight was found in seven out of eight cases, which followed nearly the same order as the carbon (pp. 55–62).

B. *Chill Cast Alloys.*—White irons. The results were similar to those obtained with the sand cast alloys, although the permanent shrinkage was not so fully marked (pp. 47–54).

8. The results obtained under 7 have given the authors the solution of the practical problem, viz. the finding of an alloy whose volume remains constant even after repeated heatings at about 900° C. Such an alloy would be a *white* iron with about 3 per cent. of carbon, and only small quantities of other constituents of which for this purpose silicon is the most important and should not exceed about 0.2 to 0.3 per cent. (p. 63).

9. *High Carbon Medium Silicon Series (J, K, and L), containing small Amounts of Graphite and 0.5 to 0.8 per Cent of Silicon.*—These alloys grew from the outset, and reached their maximum growth in fifty to sixty heats. The bar with the lowest silicon showed the smallest, that with the highest silicon the largest growth (pp. 64–68).

10. Two initially white irons, A and M, contracted for a certain number of heats and afterwards grew. It was shown that both these irons became grey on heating, and the change from shrinkage to growth was shown to coincide with the appearance of free carbon (temper carbon); and in the case of M as the free carbon increased, so did the growth. Free carbon, whether graphite or temper, was thus proved to be an indispensable factor in the growth of cast iron under these conditions (pp. 69–72).

11. It was shown by calculation with existing data, which are, however, not very satisfactory, that the growths of A and

# PLATE VI

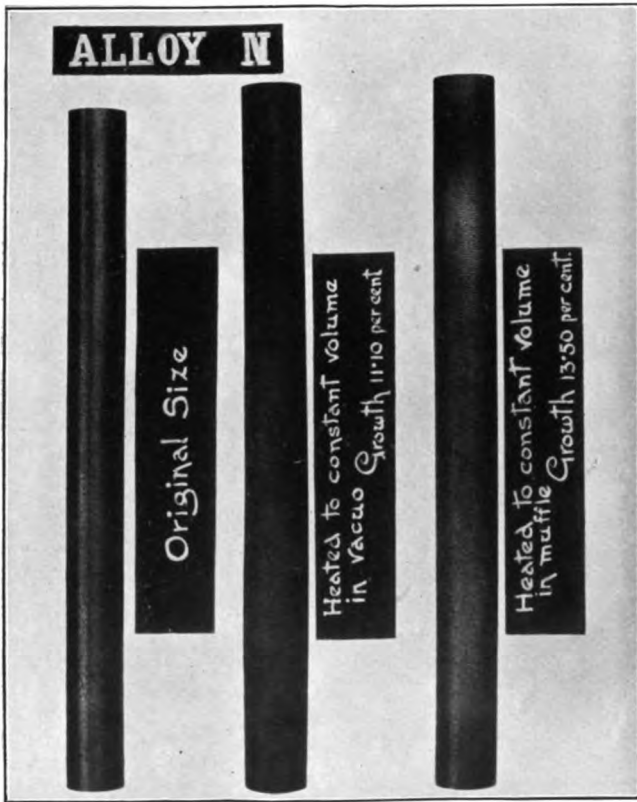


Illustrating the Difference between the Growth of S. (a) In vacuo at 900° C.  
(b) In a muffle in contact with gases at 900° C.





PLATE VII



Illustrating the Difference between the Growth of N. (a) In vacuo at  $900^{\circ}$  C.  
(b) In a muffle in contact with gases at  $900^{\circ}$  C.



M observed may be accounted for by an expansion consequent on the deposition of temper carbon in accordance with the equation—

Iron carbide ( $\text{Fe}_3\text{C}$ ) = iron ( $3\text{Fe}$ ) + temper carbon (C) (pp. 73-74).

12. The influence of silicon was next tested.

*Iron-carbon-silicon Series.*—Alloys, N to S. Carbon, 3.4 to 3.98 per cent.; silicon, 1 to 6 per cent. in steps of 1 per cent. Other constituents low and constant. Growths of between 15 and 63 per cent. were found. It was shown that they were, broadly speaking, proportional to the silicon present and far in excess of what could be caused by the conversion of combined to free carbon. In fact they were largest in the high silicon alloys which contained no carbon combined with iron (pp. 75-78 and 80-85).

13. The bars tested in 12 had been machined at haphazard, some from the gate, others from risers in different positions. The rate of growth was shown to depend on the position. Bars cut from the gate grew more quickly than those cut from risers. That end of a bar nearer the gate grew more quickly than the other. The ends of some of the bars grew more quickly than the centres.

14. Bars cut from comparable positions were next tested (NN to SS series). They were all cut from the top of a riser. They grew more slowly than the N to S series, but ultimately reached about the same growths (pp. 79 and 86-91).

15. It was quite obvious from the behaviour of this series of alloys that gases played an important part in their growth.

16. The curves of rate of increase in weight were seen to be similar to those of growth, and established an intimate connection between the two (Plates III. and IV.).

17. The final increase in weight followed the same order as the percentages of silicon. It was shown to be the resultant of three processes. (a) A partial oxidation of carbon which diminished with increase of silicon and became *nil* at 6 per cent.; (b) a probably complete oxidation of silicon, originally present as the silicide of iron, to a mixture of iron oxide and silica; (c) a partial oxidation of iron uncombined with silicon (pp. 94-98).

18. The growth of the alloys, N to S, was thus shown to be bound up with a change in the chemical condition of the silicon.

19. The gradual penetration of gases into the alloys during growth was studied microscopically in P, and the structural changes recorded. Large amounts of gas are dissolved at certain stages. Graphite is displaced from its original position—the spaces left are oxidised—and numerous small holes are formed. The structure is revolutionised (pp. 98–101).

20. *Iron-silicon Alloys*—T, U, and V. Silicon, 0·65 to 2·71 per cent.—containing no graphite, were shown not to grow appreciably after repeated heatings (pp. 102–105).

21. The influence of gases on two members of the N to S series was studied.

Alloy S, which grew 62 per cent. in a muffle, not only did not grow when heated in vacuo but actually contracted slightly (0·04 per cent.). In doing so it gave up 1·11 times its volume of gas, which consisted of 87·5 per cent. hydrogen and 12·5 per cent. nitrogen. Another bar, after being heated in vacuo, until it had ceased evolving gas, was heated in a muffle and ultimately grew 67·7 per cent. It was thus shown that the growth of this alloy is entirely due to the penetration of gases, and that the gases it originally contains have no direct share in the growth. About 47 per cent. of the penetrating gases consist of oxides of carbon. They are responsible for the oxidation of the iron silicide which is so closely bound up with the growth of this alloy (pp. 107–111).

22. The more rapid growth of the ends than the rest of the bar is readily explained, as they expose more surface to the penetrating gases (p. 112).

23. The more rapid growth of the end of the bar nearest the gate of the casting is connected with the fact that it contains more dissolved gas, but the cause of it is not as yet clear.

24. Alloy N, which grew 13·5 per cent. in a muffle, grew 11·1 per cent. when heated to constant volume in vacuo. It gave up 1·17 times its volume of gas, which was almost exclusively hydrogen (98·5 per cent.). As regards growth in vacuo this alloy thus furnished a complete contrast to S. The explana-

tion suggested is that this iron, which is very close grained, does not give up all its gas on heating. Some of it remains permanently imprisoned. Its coefficient of expansion being about 400 times that of the iron when it is liberated on heating, *e.g.* at the surface of contact between the iron and the graphite plates, the pressure will be sufficient to produce a permanent expansion (pp. 113–117).

25. N appears to be an alloy whose dissolved gases are capable of causing a large growth, at any rate where external gases are removed.

26. The growth of N in a muffle is probably caused by the combined effect of both originally dissolved hydrogen and the penetrating oxides of carbon.

27. The research has thus disclosed, among the grey irons, alloys, *e.g.* S, whose growth in air on heating is entirely due to oxidising gases penetrating their interior, and also alloys, N, where this may not be the sole agent, but where originally dissolved gases contribute to some extent to the growth.

28. The authors' results are compared with those of Mr. Outerbridge (pp. 118–119).

#### THE AGENCIES AT WORK IN THE GROWTH OF GREY CAST IRONS ON REPEATED HEATING.

Although the foregoing research has not settled all the issues it has raised, it appears possible to form a mental picture of the mechanism of the growth of annealing ovens, and other cast-iron vessels, in ordinary practice. These ovens are grey irons. They contain graphite and silicon, whose presence has been shown to be so intimately connected with growth. They also contain manganese, sulphur, and phosphorus, whose influence has not been investigated, and must therefore be left out of account. They contain some dissolved gases, and they are exposed in practice to the direct action of flame gases, the influence of both of which has been carefully studied. They consist of four main structural constituents, which may almost be considered as three.

1. A solid solution of iron silicide in iron and manganese.

2. Graphite.
3. Some combined carbon—pearlite.
4. Phosphide eutectic.

With repeated heating 3 tends to pass into 2. Only 1 and 2 will be considered.

It has been shown that after the first heating gases have penetrated to a certain depth (Fig. 3, p. 99), and also that seventeen hours' heating produces no more growth than three. A certain time is, of course, required, depending on the size of the oven, and the rate of supply of heat for the oven to acquire a steady temperature, and the volume corresponding to this. The authors' view is that, although the gases penetrate to a certain depth during this period, possibly along slits existing between the graphite plates and the solid solution of silicide in iron, and through holes which exist here and there, yet they are not actually absorbed by the solid solution until the oven is cooling. During this absorption the oxides of carbon oxidise the iron silicide, in the first instance, at the boundaries of the crystals. This reaction is accompanied by growth and incipient disintegration. Minute cracks are formed. There may be a series of minute explosions, owing to the reaction between the dissolved hydrogen and the penetrating oxides of carbon. The mechanically weak graphite may be disintegrated and forced into holes originally existing in the metal. Nitrogen enters along with the oxides of carbon, and is absorbed to some extent (see gas analyses). The net result is a slight growth of the oven by the time it has cooled to the ordinary temperature.

When the oven is next heated, the furnace gases penetrate a little farther, owing to the fresh avenues opened up by the reactions just described. On cooling these reactions are repeated, and in this way more of the iron is disintegrated, and a further growth takes place. Simultaneously, if the iron is close grained, like alloy N, hydrogen and nitrogen are liberated in the interior at the boundaries between the solid solution and the graphite. Their coefficient of expansion is so much greater than that of the solids that they exert a considerable pressure, with the result that the mechanically weak graphite is disintegrated, and appears to collect in the holes

of the casting. Where the boundary between two holes consists of graphite, it is destroyed by this action, and the two holes become one (Plate V. Fig. 4).

As the heats progress these changes continue. After each heat the external gases have penetrated a little farther (Fig. 3, p. 99). Finally, they work their way right through the oven, the rate depending on its chemical composition, physical texture, &c. When this condition is reached (Fig. 3, No. 6, and Plate V. Fig. 5), the oven has grown to its full extent. Some of the graphite has been burnt off, all the silicide of iron has been oxidised, probably to a mixture of iron oxide and silica and some iron has been oxidised as well. The main cause of growth is the disintegration of the material caused by the oxidation of the iron silicide. In close-grained irons the pressure of dissolved gases also contributes to the growth. At the conclusion of the process, the structure has been revolutionised; the oven has lost the properties of cast iron. It has no mechanical strength, and can be sawn like a piece of chalk.

The authors have no hesitation in recommending that white irons should be tried for annealing ovens instead of grey. The most suitable composition appears to be an iron with about 3 per cent. of carbon and as few impurities as possible. Of these silicon is the most important, and should not exceed 0.2 to 0.3 per cent. This iron would probably shrink slightly on repeated heating. The reason why an upper limit of 3 per cent. of carbon is suggested is that white irons higher in carbon will tend to deposit temper carbon. Where this is the case, the material will begin to grow. Even so, however, the growth will never be as much as in a grey iron. It is possible that an oven constructed of white iron may prove to be unsuitable, because it may crack on heating. Should this difficulty arise, it may perhaps be overcome by modifying the design.

The authors acknowledge with much pleasure the ready assistance given by Mr. C. A. Edwards, the demonstrator in the department, with the analytical and photographic work.



*DISCUSSION.*

Mr. J. E. STEAD, F.R.S., Member of Council, said he thought all would admit that the paper represented an enormous amount of work, very creditable work, and that they would also admit that it had added very greatly to their knowledge of the subject dealt with. He thought, however, they ought to remember that it had been recognised for a long time that white iron itself did not "grow," on alternate heating and cooling, as rapidly nor become so rapidly distorted as grey iron. White cast-iron firebars would last a very much longer time than bars made of grey iron if they did not break or snap primarily on sudden heating. The authors explained very thoroughly why that was. He believed it

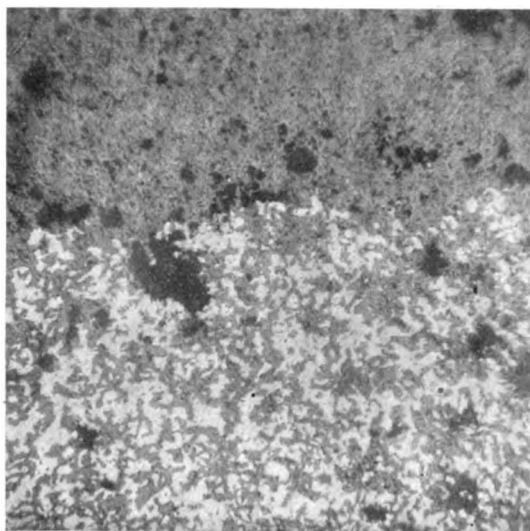


FIG. 1. - Worn-out Firebar made of Grey Cast Iron. Half tone, iron oxide; black, porosities; white, remaining unburned metal. Magnified 50 diameters.

possible that their theoretical conclusions might be qualified after more research had been made on the subject. He thought it was an interesting fact that the oxidation of grey iron followed along the sides of the graphite plates. They were easy passages or channels for oxygen, especially after the iron had been heated and then cooled again. By alternate heating and cooling, the spaces between the graphite plates were developed, and that admitted of the penetration of the oxygen. It seemed theoretically correct that white iron which was free from graphite should grow less rapidly than a grey iron. In that connection Fig. 1 (above) might be of interest. It was a photomicrograph of an old worn-

out grey cast-iron firebar, the white parts representing the still unoxidised iron and the dark parts oxide of iron. He would like to ask the authors if it were possible to state the combined carbon present in their samples, as he thought they would find that the more combined carbon there was present, the less rapid would be the oxidation or growth. He thought the results would have an added value if the combined carbon were determined.

Professor THOMAS TURNER (Birmingham) remarked that the paper to which they had listened was one which had a very high theoretical interest and, as had been mentioned by Dr. Carpenter, also had a practical application. He might perhaps mention one case which came under his notice some years back in connection with the grids of the burners of gas muffle-furnaces. When those grids became heated, they rapidly grew until, in the first place, the slits were closed up, and afterwards, when they opened the slits by breaking away part of the metal, they would close again until the burners were destroyed. There were many similar cases in which this growth took place, and, if it could be prevented, there was application for a suitable kind of metal. He was sure they were very much indebted to the authors of the present paper for the care with which those experiments had been conducted, and the accuracy of the work, which was of a kind they always associated with the name of Dr. Carpenter. From his own point of view, he regarded those expansions as coming under three heads. In the first place—and he had ventured to bring before the Institute, on a previous occasion, a paper on that subject\*—it was observed that whenever a constituent separated from a solution there was an increase of volume, a volume which could easily be measured while iron, for instance, was cooling, or brasses were solidifying. He believed Dr. Carpenter was quite correct in stating, in regard to white iron, that, as long as it remained white, there was no expansion. The moment, however, that the white iron, owing to the presence of silicon or other causes, deposited its carbon, whether it were in the form of graphite or of temper carbon, there was an expansion, and any other constituent that separated would undoubtedly lead to a similar expansion. Iron in its cast state might be regarded as to some extent in a condition of unstable equilibrium, and, naturally, when they heated the material and allowed the substances to crystallise or separate, they would get an expansion. Then, secondly, they had the point that with cast iron heated in the air they had oxidation. He was interested to see the order in which the oxidation was stated to take place, namely, that they had a separation of oxide of silicon and oxide of iron side by side. That was in accordance with what he had observed on other occasions. It was quite possible to oxidise silicon which was in solution in the iron and obtain practically pure silica. Some of the older members might remember a paper he read twenty years ago, in the days of Dr. Percy.† In those experiments

\* *Journal of the Iron and Steel Institute*, 1906, No. I. p. 48.

† "The Production of Silica from Cast Iron," *Journal of the Iron and Steel Institute*, 1887, No. I. p. 208.

a number of samples of pure silica were obtained from cast iron. He thought the fact that silica could be produced in that way was a very important part of the cause of the expansion. Then there was a third suggestion, which the authors had not mentioned, and to which he was not sure how much importance should be attached. He would be inclined to regard that expansion as pertaining to some extent to the nature of the change which they sometimes found in the case of lead. Supposing that they put a strip of lead on the roof of a building, and it was not firmly secured, the sun would shine on the lead and cause it to expand. It would expand downwards more readily than it would expand upwards. When that lead cooled at night it did not contract upwards, but remained in the position in which it expanded in the morning. They had only to leave that lead for a few years, and it would gradually walk off the roof and fall to the ground below. Now, if they imagined the iron in those samples to be in a very soft state and to be surrounded by a hard skin, it was quite conceivable to him that the particles of iron, when heated, might expand at the moment of heating, and when they wanted to shrink back they could not get back, just like the lead that could not get uphill. How far that action entered into the expansion they were considering he was not sure. He was inclined to think that it must enter into it to some small extent, but it might be so small as to be negligible. At all events they felt that in that paper there had been a distinct addition to their knowledge of that interesting subject, and that the paper had important theoretical and practical bearings.

Mr. E. H. SANITER (Rotherham) said that before starting to make any remarks on the subject-matter of the paper, he desired to compliment the authors on its form. He thought that as a literary production and also from the point of view of technical research, the Institute had had few papers for many years that had been equal to it. It was a very long paper, occupying over one hundred pages, and when he picked it up he had hesitated as to reading it. However, when he began to dip into it he felt compelled to read every word. It led him on from page to page. On one page he would ask: "Why have not the authors done so and so?" but on the next page he would find that it had been done. It was a very excellent model for other authors to follow. The part that interested him was more particularly that relating to steel, and the fact that it did not increase or decrease by repeated heatings and coolings. Some two or three years ago he drew attention to the fact that rolled steel plates, when heated and cooled a large number of times, shortened very materially. It was then suggested to him that possibly the reason of the shortening was that the elongated grain produced in the rolling took a round shape again, and thus contracted in length. At any rate the contractile stress was so great that a plate diaphragm drew a cylinder into quite an oval form instead of its being round as before. It was very interesting to find that cast steel which had not been elongated by rolling did not appear to have that tendency. The only other point was the question of why the iron grew so much. Dr.

Carpenter had explained, as Mr. Stead did some ten or more years before, in his first paper on malleable castings, that the silicon in castings oxidised without necessarily oxidising the iron, and therefore increased the bulk of the casting. Although he (the speaker) thought that in the last part of the paper Dr. Carpenter arrived at the same point as that which he (Mr. Saniter) was seeking to express, he did not think it was put as clearly as it might have been put. The point was, Why was it necessary that the iron should be cooled and heated to make it increase so much in volume? That seemed to him to be a point they had not emphasised sufficiently. His own idea was that every time the iron was annealed and expanded, whether by oxidation of the silicon or by a slight oxidation of iron, the presence of those bodies again prevented it from contracting to its old size when it was cooled, and that process was repeated when the iron was again stretched by heating. He thought that was really the explanation of the authors, but he did not think it had been worked out as far as it might have been.

Dr. W. ROSENHAIN (Teddington) said he associated himself with Mr. Saniter in expressing admiration for the work of the authors. He thought that possibly Dr. Carpenter might be interested to hear that a year or eighteen months ago, he (the speaker) made a few experiments in that connection by heating various specimens of iron in vacuo. Naturally the experiments that he made were neither on so elaborate a scale nor carried out in so accurate and complete a manner as the present experiments had been, but the results, as far as they went, confirmed those made by the authors. That was particularly the case as regards the fact that white iron would grow when heated in vacuo, when there was no other change in it except the change from combined to free carbon. On the other hand, in that particular iron they did find that the amount of growth was roughly proportionate to the time of heating, and to that extent the second paragraph on p. 119 was not of quite universal application. No doubt, however, it was intended to apply chiefly to grey irons. There was one point which perhaps it would have been desirable for Dr. Carpenter and his colleague to have mentioned, and that was to have given the Institute some idea of the rate at which the mechanical properties of the iron deteriorated when the iron underwent this process of "growth." The suggestions had been seriously made to utilise that process of growth for the purpose of renovating worn castings and making them fit again. An authoritative statement as to the injurious effect on the mechanical state of the iron would have been a most interesting addition, and could no doubt have been easily made.

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### CORRESPONDENCE.

Mr. E. ADAMSON (Sheffield) wrote that the paper was of exceptional interest to all who had long had dealings with the manufacture and use of pig iron in the foundry, as it gave formulæ which materially assisted in confirming the conclusions to which many had come during their 1909.—ii.

works experience. In May 1906 he (Mr. Adamson) drew attention to the question of graphite and its condition in pig iron, and also to the fact that its conversion was a question of temperature. For some years he had held the opinion, and stated it before another society, that graphite had a strong influence in many respects, including shrinkage, which was a near neighbour of growth, and those investigations, among other things, showed the separate influence of free carbon. Free carbon changed its form under varying conditions of temperature, &c., each of which appeared to have a distinct influence on cast iron in several particulars, and to a much greater extent than had up to that time been recognised. Therefore it was pleasing to know that that paper confirmed such conclusions.

The authors stated that all grades of cast iron did not increase equally, and he (Mr. Adamson) presumed that that would refer to grey irons, as well as including white. It could hardly be definitely concluded from the tables that combined carbon was the cause, and it would have been better had the complete analyses—including the combined carbon—been given in Table II.; also—what would have been of more importance to the practical man—the commencing fractures of those five tests, as well as the change of fracture at each treatment, as it was possible that such information would have given some explanation as to the difference in the rate of growth. It was stated that those irons were "commercial" irons, and he presumed, therefore, that they were ordinary pig irons selected from different sources, and therefore not only would the complete analyses and the fractures have been of importance, but also information as to whether they were cold-blast or hot-blast irons.

The alloys in Table VIII. were no doubt crucible cast with silicon additions; in that case the condition of the free carbon would not have been the same as in commercial irons, but it was not stated how the alloys on p. 64 were obtained, nor were the separate carbons given. Both of those were important factors in obtaining comparative data, because a total carbon 4.60 per cent. did not represent a commercial pig iron, and the excess of carbon over what would have been a reasonable saturation point might have asserted an additional influence, which would have shown itself on the fracture more particularly, especially if those had been given for each heat treatment. Those fractures would have been of interest also in view of the varying total carbons in the alloys, for it could not be denied that the total carbon had a considerable influence in the foundry. The manganese also varied, and that would also have had an influence on the tests in the heat treatment. The table on p. 65 undoubtedly showed that the higher the total carbon the greater the growth, which was to have been looked for, and it was most probable that the commencing fractures of J, K, L, and M would also have been different.

He (Mr. Adamson) would have been quite in agreement with the authors in their statement on p. 71, if they had said free carbon directly or indirectly caused the growth, as it appeared to do so much more than the total carbon shown by Stead. Neither of the equations on p. 73 gave a satisfactory explanation of the increase in growth, although the

second was the more satisfactory, but the equation required to be taken beyond the "charcoal" form of free carbon for the maximum value as an expanding agent. The influence of the different free carbons would appear to be quite as tenable a theory as that of the gases only, as named on p. 79, although undoubtedly those would be a contributory cause of the expansion.

On p. 102 the authors said that the graphitic carbon in the N to S bars was nearly constant, but they appeared to vary from 3.30 to 3.79 per cent., or practically 0.5 per cent., and therefore the results would have been slightly different on those grounds alone. The silicon contents would not have allowed a constant total carbon in commercial pig irons, and hence it would only have been possible to get the total carbon constant in the form of an "alloy" when increasing the silicon.

On p. 118 the authors appeared to consider that because Mr. Outerbridge had obtained certain results with the grey irons he used, that those would apply to all grey irons, but he (Mr. Adamson) considered that that by no means followed, for in different pig irons there was every condition present to make the results variable, even on the same silicon, sulphur, phosphorus, and manganese, and the authors were wise also not to emphatically deny Mr. Outerbridge's statement that change in volume was partly a molecular change. Personally he (Mr. Adamson) believed that that was quite possible.

The paper showed very clearly, in general principles, the growth of cast iron under certain conditions, and the authors were to be congratulated on the patience they had shown in dealing with the subject in such detail.

Mr. J. E. FLETCHER (Dudley) wrote that the interesting phenomena first described and illustrated in the contributions of Mr. A. E. Outerbridge, junior, and now further investigated by Professor Rugan and Professor Carpenter, had of course been observed for many years by workers in cast iron, wrought iron, and steel. The growth of cast-iron firebars, rolls, annealing pots, and ingot moulds, and the shrinkage of wrought iron and mild steel bars after repeated heating and cooling were every-day occurrences. The authors' conclusions, as explaining in some degree the reasons for the growth of cast iron after repeated heatings, were therefore all the more interesting and important. The presence of silicon in cast iron was shown to be largely accountable for the growth of the alloys containing it. His (Mr. Fletcher's) own investigations showed that if similar grey irons were heated repeatedly to above 900° C. and quenched in iced brine, the silicon content influenced the amount of "shrinkage." The effect of such quenching was to produce in the sample treated an outer zone or envelope rich in combined carbon, whilst the interior or core was composed of coarsely graphitic iron. The higher the silicon content the more coarsely graphitic was the core and the volumetric contraction increased with the increase of silicon. After several quenchings most of the samples fractured, apparently by bursting. Examination showed that the outer envelope of the sample, when suddenly contracting, brought about, under the great molecular pressure in that zone, the formation of cementite and a discharge inwards of the imprisoned gases carrying with

them any graphite or temper carbon which had not been converted into  $\text{Fe}_3\text{C}$ . In several cases it was noticed that in the centre of the mass, due obviously to the pressure also, there was a zone of cementite.

That gases played an important part in the questions of growth and shrinkage was indisputable, and there could be no doubt that grey cast irons absorbed gases during heating in an open furnace, although it was probable that imprisoned gases were first of all exuded through the pores which were formed by the meshwork of graphitic plates.

The exudation of gases appeared to occasion the oxidation of the graphite in the outer zones of the sample, the microscope revealing an envelope of ferrite. He (Mr. Fletcher) had often noticed that result when breaking slabs of Swedish pig iron (containing 4.0 per cent. of carbon, 1.1 per cent. of silicon, and 0.2 per cent. of manganese) which had been used as packings in large casting-annealing furnaces, such pigs having been repeatedly heated to about  $900^\circ\text{C}$ . and cooled slowly to air temperature. (See Fig. 2.)

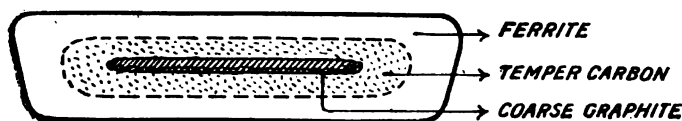


FIG. 2.

Mild steel castings after repeated annealings had been observed to be permanently smaller, and in one case which came under the writer's notice a large ring of some 16 feet in diameter was permanently reduced, by reannealing several times, by over 1 inch in diameter. There was no abnormal scaling to account for that reduction. It would appear that volumetric changes brought about by repeated heatings with slow cooling or with quenching were intimately connected with the formation, in the masses tested, of, in the first case graphite, and in the latter cementite. Cementite was formed when the graphite was imprisoned within the contracting mass of a quickly quenched alloy, the accompanying intermolecular pressure being enormous. On the other hand graphite grew where (as in heating and slow cooling) the mass was freed from internal pressure by the increase of porosity, although in the first instance the pores or interstices between the ferrite crystals were opened by the expansion by heat of the imprisoned gas bubbles left there during the original solidification of the carbon iron alloy.

It was interesting to learn that the silicide of iron present during repeated heatings was converted into silicate (p. 125). That confirmed his (Mr. Fletcher's) observations when studying the effect of the distortion and cracking of the inner surfaces of heavy ingot moulds. The disintegration of those surfaces was always accompanied by the burning off of the graphite and the formation of a shell or coating of iron oxide and of silica, possibly a silicide of iron, for the surface was at times glazed in a manner suggestive of slag formation. Under that "rotten" lining the unburnt metal was coarsely graphitic.

The suggestion that an alloy low in silicon, and having a carbon con-

tent not exceeding 3.0 per cent., could be used for such articles as annealing pots was valuable. It would be interesting to hear that such an alloy could be employed successfully. Castings of that composition, whether made in chills or sand, had a pronounced crystalline structure, the crystals arranging themselves at right angles to the cooling surfaces of the mould, and unless free from sharp angles of uniform thickness, and well fed and clean at the running gits or feeders, such castings would crack when subjected to rapid heating up from the cold state. On the assumption that such an iron, containing 3.0 to 3.5 per cent. of carbon and 0.3 to 0.4 per cent. of silicon, might answer well for the tools of shingling hammers subject to constant contact with liquid cinder and white-hot iron puddled balls, he (Mr. Fletcher) had made experiments in that direction which were found to be successful when the castings were allowed to cool down exceptionally slowly or afterwards annealed. The waste on the faces of the tools due to the scouring action of the cinder was reduced. Ordinary grey castings "grew" quickly on the face and rapidly disintegrated. The difficulty with white iron castings was that they were liable to be brittle. The presence of manganese modified the action of silicon in such castings for the reason that graphite formation was hindered, and in the experiments with the above-mentioned shingling hammer tools, the presence of 0.5 per cent. of manganese permitted silicon up to 0.6 or 0.7 per cent. to be used to the benefit of the castings, which did not disintegrate so rapidly and were less brittle. That action of manganese on the silicon could not, in his opinion, be ignored, for there was little doubt that the manganese in those alloys seized upon the carbon to form  $Mn_3C$  before the cementite ( $Fe_3C$ ) separated out as a constituent of the eutectic. Graphite was thus less readily isolated. The steps in the solidification of alloy L, for example, would be thus:—

1st. Separation of ferrite crystallites from liquid solution.

2nd. Solidification of crystals of  $Mn_3C$ .

3rd. Solidification of crystals of FeSi surrounding the ferrite crystals.

4th. Solidification of eutectic.

It might be found that the graphite formation was entirely due to the action of silicon or of the silicide, FeSi, on the eutectic, which, according to the rate of its solidification, was more or less graphite free. It would seem that the envelope of FeSi about the ferrite crystals prevented such crystals from becoming carburised by the free carbon which was then precipitated as graphite. If, therefore, the alloys were considered as mixtures of eutectic (4.3 per cent. carbon, 95.7 per cent. iron), manganese, carbide, and silicon, the relations  $\frac{\text{silicon per cent.}}{\text{eutectic per cent.}}$  was of interest as bearing on the question of volumetric change during repeated heating. It was obvious that the steel alloys, G, H, I, T, U, and V, could not be compared with the remainder, as the latter did not contain the 4.3 per cent. eutectic. It would be noticed that alloy C, where the value of  $\frac{\text{silicon per cent.}}{\text{eutectic per cent.}}$  was lowest, was the one which grew least under the repeated heat treatment and that which exactly complied with the authors' proposal for a "non-growing" metal.



The accompanying table gave the calculated eutectic percentage in the alloys and the value of the ratios  $\frac{\text{silicon per cent.}}{\text{eutectic per cent.}}$  in each case. If the values given in columns 2, 7, and 8 were plotted, it would be seen that there was a close relation existing between the eutectic and silicon contents and the volumetric growth, whereas the carbon content was not directly related to the "growth" values.

Alloy.	Carbon.	Manganese.	Silicon.	Carbon corrected for Manganese.	Eutectic.	Ratio. Silicon per Cent. Eutectic per Cent.	Volumetric Growth.
1.	2. Per Cent.	3. Per Cent.	4. Per Cent.	5. Per Cent.	6. Per Cent.	7.	8. Per Cent.
A .	4.03	0.15	0.243	4.02	93.5	0.26	+ 6.86
B .	3.70	0.16	0.233	3.69	86.0	0.27	- 0.91
C .	3.08	0.17	0.172	3.07	71.5	0.24	- 1.76
D .	2.59	0.12	0.146	2.58	60.0	0.248	- 1.67
E .	1.96	0.20	0.215	0.195	45.5	0.477	+ 1.14
F .	1.58	0.17	0.168	1.57	36.5	0.46	+ 0.39
G .	0.99	0.19	0.233	0.97	22.5	1.02	+ 0.19
H .	0.55	0.20	0.182	0.53	12.4	1.45	+ 0.113
I .	0.15	0.15	0.186	0.14	2.56	7.25	+ 0.8
J .	4.60	1.26	0.79	4.51	107.00	0.74	+13.9
K .	3.90	1.09	0.69	3.20	74.5	0.93	+10.4
L .	3.60	1.02	0.65	3.40	79.0	0.825	+ 8.7
M .	3.02	0.86	0.50	2.96	69.0	0.725	+ 6.2
N .	3.98	0.25	1.07	3.96	92.0	1.16	+15.4
O .	3.98	0.23	0.179	3.96	92.0	1.95	+23.46
P .	3.79	0.25	2.96	3.77	87.5	3.40	+32.85
Q .	3.76	0.27	4.20	3.74	87.0	4.82	+43.9
R .	3.79	0.30	4.83	3.76	87.5	5.5	+59.5
S .	3.38	0.30	6.14	3.35	78.0	7.9	+63.0
T .	0.17	0.17	0.65	0.16	3.75	17.15	- 0.025
U .	0.18	0.19	1.10	0.17	3.96	27.8	nil
V .	6.19	0.20	2.71	0.18	4.2	64.2	+ 0.394

Mr. W. H. HATFIELD (Sheffield) desired to congratulate Professors Rugan and Carpenter on their excellent paper. On the publication of Mr. Outerbridge's original paper, he (Mr. Hatfield) had been at some trouble to repeat that gentleman's experiments, and was successful in producing the growth of cast iron which Mr. Outerbridge described, and came to the conclusion that the expansion was due to oxidation. On studying Mr. Outerbridge's original paper, he had been struck by the fact that the specific gravities given therein did not coincide with the figures of expansion. That question was completely cleared in the exhaustive research of Professors Rugan and Carpenter by the consistent increase in weight obtained in their experiments, an increase which had not been recorded by Mr. Outerbridge.

It might be of interest, in confirmation of the authors' views, to record an incident connected with the use of chills in the iron foundry. At the works with which he (Mr. Hatfield) was connected, the same grey cast-iron chills had been, some years before, used repeatedly in producing one particular series of castings. As time went on it was found that the

dimension of the casting in the neighbourhood of the chill showed considerable variation, and the trouble was directly traced to that characteristic of cast iron which had been so thoroughly investigated by the authors. It would be interesting to know that the solution of the difficulty had been found in using white iron chills low in silicon, which retained their original dimensions even after considerable service.

Mr. COSMO JOHNS (Sheffield) wrote expressing his appreciation of the value of the results obtained by the authors as a result of their carefully planned experiments. They went to show that, with the material generally used for annealing ovens or boxes, there could be little prospect of preventing the troublesome increase in volume and consequent deformation so well known. It was just those cast irons that contained free graphite, and thus normal silicon, that best withstood the repeated heatings and coolings to which they were necessarily subjected to in annealing work. Using a low silicon iron would, from the results of the authors' work, give a material that would not "grow," but such a white iron could only with great difficulty be treated so as to convert its combined carbon into the graphitic form, and would probably have fractured before that change had been accomplished. It would be interesting if the coefficient of expansion of those two classes of irons, up to, say, 900° C., were determined. The authors were evidently working in the right direction, and it was to be hoped that they would succeed in solving the problem of indicating one of the iron-carbon alloys, which, while retaining the fusibility, and therefore economy of production of the ordinary cast irons, would yet be free from that annoying property of increasing in volume when in use. The chief difficulty seemed to lie in overcoming the liability to fracture during the earlier heatings of those low silicon alloys.

Mr. A. E. OUTERBRIDGE, junior (Philadelphia), wrote that he was pleased to find that the authors had considered his original investigation as of sufficient novelty and importance to have induced them to devote so much time and labour to a continuation of the study. He was also gratified to note that the authors were usually in general agreement with him in places where the same ground was traversed. In the few instances where opposite conclusions were drawn, he was agreeably surprised to discover that the internal evidence in the paper itself, upon which those diverse views were formed, proved, very conclusively indeed, the correctness of his original statements. He would cite, as an example, p. 118, paragraph 1. The authors' experimental results with the two alloys (A and M) were in disagreement with his opinion that "white iron, in which nearly all of the carbon was in the combined form, did not expand sufficiently to overcome the original shrinkage even after all the combined carbon had been changed to graphite," and conclusively showed that it did. A study of the authors' tabulated tests conclusively showed that it did not. The linear contraction or shrinkage of white cast iron on cooling in small bars from liquid to solid was about 0.3 inch per foot as compared with about 0.125 inch per foot for ordinary grey foundry

iron. The alloys A and M referred to were white iron bars, approximately 6 inches in length; the original shrinkage of the metal of the bars was therefore about 0.150 inch in each bar. Again, Table XXXI. on p. 69 stated that the original length of alloy M bar was 6.1317 inches, and the final increased length, after sixty-eight heatings, was 6.2040 inches, a total linear expansion of 0.0723 inch, as compared with original shrinkage of the metal of that bar of 0.153 inch. In other words, it had recovered, after sixty-eight heatings, a little less than one-half of the original shrinkage. Table XI., p. 46, stated that the original length of bar alloy A (also white iron) was 5.9587 inches, and the final length, after no less than ninety heatings, was 6.0870 inches, a total linear expansion of 0.1283 inch, as compared with the original shrinkage of 0.150 inch. It therefore appeared from those tables of expansions that in neither of the cases cited did the white iron bar expand sufficiently to overcome the original shrinkage, even after all the combined carbon had been changed to the graphitic form, and that agreed with practical experience in annealing white malleable iron castings. There were a number of other tables of tests of white iron bars, subjected to repeated heatings, in the paper, all proving the accuracy of his statement.

In 1904 he exhibited bars of white cast iron and of grey cast iron that had been subjected, side by side, in a closed steel pipe, to one hundred heatings. The white bars had not increased in size sufficiently to overcome the original shrinkage, while the grey cast-iron bars had not only recovered the original contraction, but had increased over 40 per cent. in cubic volume in addition thereto, without developing visible cracks. On p. 118, paragraph 2, appeared the following: "Mr. Outerbridge states that his 'enlarged bar (40.98 per cent.) weighed precisely the same as before treatment.' The authors have great difficulty in accepting this statement which is at variance with their entire experience. His bar was heated in an iron pipe, the ends of which were stoppered with clay, at a temperature of 800° C.; that is, under conditions which permitted the penetration of oxidising gases, and were thus very similar to those used by the authors. In not a single one of the numerous cases examined by them did the weight remain constant." With due deference to the experience of the authors, he was obliged to assert that the conditions were very dissimilar, and quite sufficiently so to account for the different effects.

When he at first heated his bars exposed in a muffle of a furnace, as did the investigators, he found that a constant stream of air passing over the white hot bars caused "scaling" due to oxidation, and that oxidation penetrated the metal in a manner analogous to the penetration of carbon in case-hardening mild steel. That scaling always caused an increase in weight of the expanded bars. Throughout the paper the authors referred to this "scaling," which was a necessary accompaniment in their method of heating. He (Mr. Outerbridge) stated in his original communications that in many instances, to prevent scaling, he filled the spaces between the bars, in the metal tube in which they were enclosed, with charcoal, but even without that precaution there was sufficient carbonaceous material present to prevent scaling, and the conditions,

moreover, did not permit of the penetration of oxidising gases and were therefore not similar to those observed by the authors.

On p. 32 it was stated that "the authors have been in communication with Mr. Outerbridge, and understand that he still adheres to these views, and that he has not published any later experiments bearing on them." He (Mr. Outerbridge) was not aware that the authors were preparing a paper for publication, as the only communication he had received was a letter from Professor Rugan in October 1908 asking for a list of his publications. Otherwise he would have been pleased to have pointed out some other apparent discrepancies between opinions and facts as developed in those investigations. He still adhered to his original views as set forth in his sundry communications to scientific bodies in America on the large subject of "The Mobility of Molecules of Cast Iron" of which the growth of that metal after repeated heatings was a subsidiary branch, and one which he had been continuously examining for ten or more years before his first communication on the matter had been offered for the criticism of scientists and practical founders.

In a further communication, Mr. Outerbridge wrote that, in more carefully studying some of the tables of tests in which certain bars, designated "white" iron, showed a slight contraction, he was surprised to observe from the analyses that quite a number of the bars were not cast iron at all, but had the composition of steel, thus:—

	Carbon.	Silicon.	Manganese.	Sulphur.	Phosphorus.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Table XVII. .	0.99	0.23	0.19	0.015	0.012
" XVIII. .	0.55	0.182	0.20	0.013	0.014
" XIX. .	0.15	0.186	0.15	0.040	0.017
" XXIII. .	1.96	0.215	0.20	0.013	0.015
" XXIV. .	1.58	0.168	0.17	0.015	0.014
" XXV. .	0.99	0.233	0.19	0.015	0.012
" XXVI. .	0.55	0.182	0.20	0.013	0.014
" XXVII. .	0.15	0.186	0.15	0.040	0.017

In all his own papers he had clearly shown the remarkable difference in behaviour between steel and cast iron when subjected to repeated heating and cooling, one contracting, the other expanding. Thus, "Wrought-iron and steel bars subjected to the same repeated heating and cooling, in a closed tube, all contracted slightly in cubic dimensions. The average contraction of such bars, after about sixty heatings in a closed pipe, was  $\frac{1}{8}$  inch per foot." \*

He was, of course, much pleased to find that those tests showing contraction of steel bars corroborated his observations and statements so fully regarding the action of repeated heatings on steel, but he could not but think it an unfortunate oversight that in the paper entitled "The 'Growth' of Cast Irons after Repeated Heatings" there should be no

\* See *Transactions of the American Institute of Mining Engineers*, 1905, vol. xxxv. pp. 223-244.

indication, in the eight tables noted, to show that the alloys were steel and not cast iron.

As an indication of the practical application of the phenomena under discussion, Mr. Outerbridge instanced a statement made by Mr. Thos. Devlin,\* before the Philadelphia Foundrymen's Association, respecting the saving of several tons of a condemned cast-iron pipe by reheating, and the similar expansion of a worn piston reported at the same time.

Mr. C. H. WINGFIELD (London) wrote giving his experience when engaged as a technical witness in a recent lawsuit, in which the case turned largely on the failure of a cast-iron chimney surrounded by a vertical brick casing to create a proper draught. The chimney was designed to slide freely through the top of the brickwork, but the bricklayers had built the latter with a ledge projecting inwards over the cast iron. As a result, not only did the weight of brickwork at first cause the expansion to force the lower end of the cast-iron flue downwards and break joints, &c., but the iron was permanently lengthened, and actually lifted the upper part of the brickwork off a cemented joint, and held it permanently free of the lower part of the brick casing.

He had desired, at the time of the lawsuit, to point out that fact, citing Outerbridge's experiments to show that cast iron "grew," but other "experts" treated the matter with polite incredulity, and the case was lost. It was in consequence of the ignorance which he found existed on that subject that he suggested it to Dr. Carpenter as worthy of attention. He thought all engineers would be grateful to the authors for the thoroughness in which they had dealt with it, and for the interesting and useful way in which they had presented their results. Not the least useful part of the paper was the index on the second page.

He saw on that page that "range fittings" were said to grow. It was within every one's experience; that the firebars, especially those in front of open ranges, grew till they bent and were too long to be removed or replaced. He did not, however, think the top plates grew, although they often became red-hot. Could it be that they were made of white iron? He had never seen one buckle or tighten in its place. Those members who were unable to obtain access to the original papers cited by the authors would find the cream of Mr. Outerbridge's results in an article published by *Engineering* (vol. lxxvii. p. 56).

The authors appeared to have proved quite conclusively that, if gases are excluded, the iron did not grow, and that the gases did not merely act mechanically, as suggested on p. 33 of their paper in the reference to Mr. Outerbridge, but chemically, by forming oxides of iron and silicate of iron, which occupied more space than the unoxidised metal.

The enormous force exercised by oxidation might sometimes be seen in the case of old iron railings and gates. In an instance he had seen on Chiswick Mall, the iron railing of what used to be the house inhabited by Thackeray's original "Becky Sharp" forcibly bent, where two ends overlapped, by the rust which had formed between them. He understood that the authors referred the growth of the whole to that of the oxidised

\* *American Machinist*, July 7, 1909.

parts. He had hoped that the authors would have been able to have given a diagram plotted over a temperature base showing the composition of alloys of iron which would have varying degrees of maximum growth. Perhaps they might do so in a future paper, but the problem was complicated by the fact that two elements, carbon and silicon, had each a considerable effect. The photographs in Plate V. were of especial interest, reminding one, as they did, of Dr. Carpenter's similar photographs of the penetration of gases in nickel steel wire given in his paper read at the York Meeting of the British Association in 1906.\*

Professor CARPENTER, replying on behalf of Professor RUGAN and himself, thanked the members who had taken part in the discussion on September 28 for their appreciative references to the work, and for supplying information confirmatory of the main conclusions to which the research had led them. Mr. Stead had asked for the combined carbon in the samples. Alloys A to I inclusive (Table VIII.) and alloy M contained only combined carbon. Alloys K and L were almost entirely white irons, and contained only minute amounts of graphite. Almost the whole of their carbon was combined. Table XXXII. gave the combined carbon in alloys N, O, and P as 0.64, 0.68, and 0.30 per cent. respectively. The whole of the carbon in Q, R, and S was in the form of graphite. Alloys T, U, and V contained only combined carbon. Mr. Stead said, "He thought . . . that the more combined carbon there was present, the less rapid would be the oxidation or growth." Their results certainly pointed to that conclusion; but in order to test the point strictly it would be necessary to experiment on an alloy which contained initially only combined carbon. Samples of such an alloy would have to be treated so as to convert increasing amounts of the combined carbon into free carbon, until, in the last sample, only free carbon was present. Care would of course have to be taken that no oxidation took place during that preliminary treatment. The determination of the rate of growth of such a series of alloys by subsequent heating in a muffle would then give the answer to Mr. Stead's question. The authors were much obliged to him for submitting a photomicrograph of a worn-out grey, cast-iron firebar. That was comparable with their Fig. 5, Plate V. Professor Turner and Mr. Saniter had independently suggested another cause of the growth of cast irons. Professor Turner said (p. 128), "If they imagined the iron in those samples to be in a very soft state and to be surrounded by a hard skin, it was quite conceivable to him that the particles of iron, when heated, might expand at the moment of heating, and when they wanted to shrink back they could not get back. . . . How far that action entered into the expansion they were considering he was not sure. He was inclined to think that it must enter into it to some extent, but it might be so small as to be negligible." Mr. Saniter said (p. 129), "Every time it" (*i.e.* the iron) "was annealed and expanded, whether by oxidation of the silicon or by a slight oxidation of the iron, the presence of those bodies again

\* Published in *Engineering*, vol. lxxxii. p. 222.

prevented it from contracting to its old size when it was cooled, and that went on when it was again stretched by heating. He thought that was really the explanation of the authors, but he did not think it had been worked out as far as it might have been." The authors agreed that it was very probable that such a cause was operative in the growth of their cast irons. It would follow from that reasoning that after a very few heats such irons would be under considerable tension at the ordinary temperature. That might partly account for the cracking which took place in the specimens and for the rapid deterioration of their mechanical properties.

With regard to the relation between the amount of growth and the time of heating—the point raised by Mr. Rosenhain (paragraph 2, p. 119)—applied, as was there stated, to "commercial cast irons." Such irons always contained graphite. It was not intended to apply to white irons, because in their case the cause of growth was different, and, as shown on pp. 71–74, might in the present state of knowledge be explained by the conversion of combined into free carbon. In such cases the growth would be expected to be "roughly proportionate to the time of heating," as Mr. Rosenhain found. The relation between "growth" and deterioration of mechanical properties was forming the subject of a separate investigation by Professor Rugan, who hoped to present a paper with his results before long.

Passing to the correspondence, they were much obliged to Mr. Adamson for his contribution, and were glad that in the main their conclusions agreed with his, drawn from works experience. He asked for the "complete analyses" and "the change of fracture at each treatment" of the three alloys mentioned in Table II. The latter request was hardly reasonable, as it would have involved the treatment of 495 specimens. Complete analyses were not made because the alloys were merely studied at the outset of the research from the point of view of growth of commercial irons. They did not fit into any of the latter series of alloys whose composition was rigidly specified. In view of their experience gained in the research, they thought that the differences in the rate of growth were probably due to differences in the amount of originally dissolved gas (see p. 113). They were unable to state whether the irons were cold-blast or hot-blast. With regard to Mr. Adamson's statement that "the alloys in Table VIII. were no doubt crucible cast with silicon additions, in that case the condition of the free carbon would not have been the same as in commercial irons," they said (p. 44), "In no case was any graphite present; the alloys were exclusively white irons." All the alloys except those given in Table II. were cast from crucibles. Alloy M (p. 64) was white, alloys K and L almost white. Only J contained an appreciable amount of graphite. Here again the demand for the change of fracture after each heat treatment was unreasonable, and would have necessitated the use of an impossibly large number of specimens. Mr. Adamson said further, "The table on p. 65 undoubtedly showed the higher the total carbon the greater the growth, which was to have been looked for." They did not agree with that statement. The research had shown that there was no direct relation between total

carbon and growth, but that there was an intimate relation between the percentages of silicon and growth. In that table the growth followed the same order as the silicon. He went on to say, "He would have been quite in agreement with the authors in their statement on p. 71 if they had said free carbon directly or indirectly caused the growth." If Mr. Adamson would turn to p. 71 (lines 8 and 9) he would see that that was exactly what the authors had said. With regard to equation B on p. 73, they knew of no form of carbon whose specific gravity was less than 1.45. Mr. Adamson appeared to think that an even less dense variety existed. Any data he could publish as to such a variety would be very welcome. His statement that "the influence of the different free carbons would appear to be quite as tenable a theory as that of the gases only, as named on p. 79, although undoubtedly those would be a contributory cause of the expansion," showed that he had not quite appreciated the fact that the cause of the growth of a white iron which became grey on heating, such as A or M, was quite different from that of the growth of an initially grey iron. The former was probably a volume change consequent on the separation of free from combined carbon; the latter was mainly the disintegration due to the oxidation of iron silicide, and probably also the permanent stretching of unoxidised iron held in a skin of hard silica and iron oxide. Mr. Adamson's reference to p. 102 had already been dealt with. They quite agreed with him that the influence of phosphorus and manganese should be taken into consideration. That was why in the alloys hitherto investigated those elements had been kept as low as possible in order that the effect of carbon and silicon might be made clear. At the present moment one of the authors (Dr. Carpenter) was engaged in determining the influence of phosphorus. Manganese would next be taken up. Sulphur was usually present in such small amounts that its influence could only be slight.

The authors were much obliged to Mr. W. H. Hatfield for his very appreciative contribution. His agreement with their conclusions as to the cause of the growth of grey irons was very satisfactory to them, and his reference to Mr. Outerbridge's work timely, in view of the latter's communication. They were especially interested to know that he had been able to use white iron chills low in silicon in producing castings, and that those chills had kept their original size. Although he did not say so, they gathered that they had not cracked after considerable use.

Naturally the authors were much interested in Mr. Outerbridge's communication. His first point was in connection with the growth of white irons, such as A and M, which after repeated heatings deposit temper carbon. It was quite clear that the discrepancy between his and their results was not real, but was due to their using the word "shrinkage" in a different sense. Their results were really in good agreement. Mr. Outerbridge calculated shrinkage on the fluid metal, and took an average figure of 0.3 inch per foot. Doubtless that figure might vary somewhat with white irons of varying composition. But taking that as a mean figure, the authors' figures amply bore out his statement that the growth due to the separation of temper carbon was not sufficient to overcome the original shrinkage of the liquid metal in solidifying and cooling to



the ordinary temperature. It would, however, have been clear to readers of the paper that the authors, in using the word shrinkage, referred to the contraction which the solid alloy underwent in almost all cases during the first heats. The figures for A and M showed that so far as existing data permitted of an opinion being formed, the growth due to the separation of temper carbon was more than sufficient to overcome that kind of shrinkage. The authors regretted having misinterpreted Mr. Outerbridge in that matter. In order to clear up the misunderstanding a footnote had been inserted on p. 118 of the paper.

With regard to paragraph 2, p. 118, the position was somewhat unsatisfactory. Mr. Outerbridge still maintained that his enlarged bar (40·98 per cent. growth) weighed precisely the same as before treatment, even though it was heated in an iron pipe, the ends of which were stoppered with clay at a temperature of 800° C. It was well known to any one who had conducted annealing experiments that such an envelope did not constitute a gas-tight enclosure, but that at that temperature the iron was pervious to gases. So far as the authors had been able to ascertain, Mr. Outerbridge has never published the determinations of the weight of the bar. That was to be regretted, because the question could not really be discussed without those figures. For instance, when he said that "the enlarged bar weighed precisely the same as before treatment," it was natural to ask, "To what degree of sensitivity? Was it to 0·0001 gramme, or 0·001 gramme, or 0·01 gramme, or what?" All the authors' weighings were carried to 0·0001 gramme, and it was quite inconceivable that Mr. Outerbridge's bar was constant to that degree of accuracy. The authors' experiments with alloys N and S, heated in vacuo, showed that the weight might vary within 2 or 3 decigrammes. They were obliged to insist on that point because it was of fundamental importance. Their experiments with the grey irons, N to S inclusive, showed how intimately connected were growth and increase of weight.

In his communication Mr. Hatfield stated that he had repeated Mr. Outerbridge's experiments, and had come to the conclusion that the "expansion was due to oxidation," and that "he had been struck by the fact that the specific gravities given therein did not coincide with the figures of expansion." That constituted indirect evidence that the weight of Mr. Outerbridge's bar must have changed during his experiments. He (Mr. Outerbridge) went on to say that "in many instances to prevent scaling he filled the spaces between the bars in the metal tube in which they were enclosed with charcoal." It would be somewhat surprising if under those conditions no increase in weight took place. The position was unsatisfactory because, in the face of those facts, Mr. Outerbridge had not submitted any evidence tending to show that his bar did not increase in weight, but merely reasserted his original statement. On that point, therefore, there was an "impasse." Further, Mr. Outerbridge had not correctly interpreted the authors' paper when he wrote, "Throughout the paper the authors referred to the 'scaling' which was a necessary accompaniment in their method of heating." That was not the case. There was no perceptible scaling of the grey irons, N to S inclusive; the surfaces were merely dulled. The alloys

which scaled perceptibly were the white irons, A to I. That was most marked on alloys E to I, which, as Mr. Outerbridge remarked, were really cast steels. It was therefore incorrect for him to attribute the increase in weight with growth to scaling. As the authors' photomicrographs on Plate V. showed, the iron silicide throughout the bars was oxidised, and only when that was complete did they stop growing.

In his further communication Mr. Outerbridge had discovered that certain alloys, prepared by the authors, were not cast irons but cast steels. His criticism of the title of the paper showed that he had not quite understood the reason for experimenting with them. At the outset, when it was desired to determine the influence of carbon on the growth of iron, it was necessary to start from the alloy lowest in carbon that could be made, which was of course a mild steel, and gradually increase the carbon until a 4 per cent. alloy was reached. Very few indeed of the alloys experimented with were strictly speaking "cast irons," but it was necessary to use them to deduce the influence of carbon and silicon. The impression left on the writer's mind by Mr. Outerbridge's contribution was that the latter felt somewhat aggrieved that any one else should have ventured to work in the field selected. He stated that "he still adhered to his original views . . . on the large subject of the mobility of molecules of cast iron . . . one which he had been examining continuously for ten or more years before his first communication on the matter had been offered for the criticism of scientists and practical founders," thus implying that the authors' results had in no way modified his opinions and did not constitute a contribution of any moment to the subject. That was an aspect of the matter which did not call for any direct answer on their part, and they were content to refer him to the discussion and correspondence contributed by the other gentlemen for an independent judgment.

The contribution by Mr. C. H. Wingfield was of great interest, particularly his narration of the growth of the cast-iron chimney and the incredulity of the "experts" that such an iron could grow on heating. With regard to his wish that the authors could have given the chemical "compositions of alloys with varying degrees of maximum growth," they had purposely abstained from doing so until the influence of phosphorus and manganese had been determined. Dr. Carpenter hoped, in a future paper, to be able to give some data relating to that matter.

The difficulty of producing a non-expansible cast iron which did not crack during the earlier heatings was well put by Mr. Cosmo Johns. Mr. Hatfield's contribution, however, showed that he had overcome that difficulty in the case of white iron chills used in the iron foundry.

Mr. J. E. Fletcher's communication unfortunately arrived too late for any detailed study. It was a scientific contribution of great value. A number of interesting observations were brought forward bearing directly on the problem, and suggesting further experiments. In that respect it was most helpful.

## UNIFORM MOISTURE IN BLAST.

EXPERIMENT CARRIED OUT AT CLARENCE  
IRONWORKS, 1909.

BY GREVILLE JONES (MIDDLESBROUGH).

THESE experiments were the outcome of several interviews which the author had with Mr. R. S. Moore on the question of the uniformity of blast as supplied to blast-furnaces, as it was considered, after careful study of the various discussions by several eminent persons on Mr. Gayley's paper on "Dry Air," that there was still some element of doubt as to whether the principal saving in fuel was due to the uniformity of blast or to its dryness.

As soon as the matter was placed by the author before Sir Hugh Bell, he readily consented for the experiment to be carried out on the lines proposed by Mr. Moore, the latter having, as a matter of fact, provisionally protected the idea of extracting the peaks or high percentage of moisture from the air during the summer months, and keeping the moisture constant by the addition of steam, if found necessary, during the winter months.

After due consideration, it was decided that it would be advisable to carry out the experiment at No. 9 furnace on the "New Side," for the following reasons:—

- (1) No. 10 furnace (working alongside No. 9 furnace) was of the same dimensions, and
- (2) Both furnaces were worked by separate blowing-engines, and supplied with the same quantity of air.
- (3) Each furnace had four stoves of the same size.
- (4) Both furnaces received their common supply of iron-stone, limestone, and coke from the same source.
- (5) They were both new furnaces, built in 1908, and blown as follows:—

No. 9	.	.	.	.	September 17.
No. 10	.	.	.	.	June 9.

- (6) Each furnace was burdened for foundry iron, and carried the same total load. The silicon in the iron was required to be between 2.50 per cent. and 3 per cent.

The experiment was continued for four weeks, the first week being occupied in increasing the moisture up to the desired quantity.

As careful observations had been made with wet and dry bulbs outside the engine-house prior to the commencement of the experiment, it was agreed that it would be better not to exceed 4 grains of moisture in the aggregate.

The procedure was to connect up to the cold-blast main a steam-pipe from the main boiler plant, and fit it with a calibrated steam-valve, so arranged that, for a minute movement of the valve, a certain quantity of steam would be admitted, representing so many grains. A pipe was also connected from the cold-blast main into a wooden case, where a wet and dry bulb was hung, with, in addition, an ordinary hair hygrometer, the instrument having previously been calibrated. There was also a connection from the hot-blast main to a wet and dry bulb, which gave an additional check. As a further check upon these instruments, the head chemist of the works (Mr. Weldon Hanson) very carefully took samples of both hot and cold blasts gravimetrically for five hours each day. The gases were also taken daily over the same period.

The diagrams (Plates VIII. and IX.) show the results obtained, which are indicated by the following curves:—

No. 1. First line gives the records taken by the hair hygrometer—hot blast.

No. 2 shows to what extent the steam-valve was open.

No. 3 gives records of air outside engine-house.

Nos. 4 and 5 show the silicon and sulphur respectively.

Readings were taken every fifteen minutes from February 11 at 2.30 P.M. to 2.30 P.M. on February 12, and subsequent readings every thirty minutes until the experiment was completed.

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The following are the author's observations on the experiment:—

As to the working of No. 9 furnace, no appreciable difference was found. The average analyses of the pig iron were:—

<i>Before Experiment.</i>										Per Cent.
Silicon	.	.	.	.	.	.	.	.	.	2·97
Sulphur	.	.	.	.	.	.	.	.	.	0·037

<i>During Experiment.</i>										
Silicon	.	.	.	.	.	.	.	.	.	2·76
Sulphur	.	.	.	.	.	.	.	.	.	0·036

showing a reduction of 0·21 per cent. in the silicon, and 0·001 per cent. in the sulphur, the latter of which is of no account, and may be due to the slight excess of lime shown in the average slag analysis.

Comparing similar figures for No. 10 furnace, we have—

<i>Before Experiment.</i>										Per Cent.
Silicon	.	.	.	.	.	.	.	.	.	2·89
Sulphur	.	.	.	.	.	.	.	.	.	0·045

<i>During Experiment.</i>										
Silicon	.	.	.	.	.	.	.	.	.	2·84
Sulphur	.	.	.	.	.	.	.	.	.	0·040

Taking the records for Nos. 9 and 10 furnaces, the author finds that during the experiment No. 9 had eleven slips and No. 10 seven slips.

During the period that No. 9 furnace had uniform blast, no alteration was made in the burdens or temperatures of the blast at Nos. 9 and 10, and the speeds of the engines were kept the same on both furnaces.

*Coke Consumption.*—The quantity used per ton of pig iron made at No. 9 furnace (no deduction for breeze) was—

				Cwts.
4 weeks previous to experiment	.	.	.	21·98
4 „ during „	.	.	.	22·08
4 „ after „	.	.	.	21·86

At No. 10 furnace the results were as follows :—

				Cwts.
4 weeks previous to experiment	.	.	.	22·06
4 „ during	„	.	.	22·20
4 „ after	„	.	.	21·80

*Comparison of Hygrometers.*—In order to be sure that the readings of the wet and dry bulbs hygrometer in conjunction with the Glaisher's tables gave accurate results, the instrument was checked gravimetrically, and also with Lambrecht's dew-point instrument. The results of the experiment are as follows :—

	Grains.	Grains.	Grains.	Grains.
Gravimetric . . . .	2·70	3·26	2·41	3·49
Lambrecht's dew-point . .	2·70	3·22	2·30	3·22
Wet and dry bulb . . . .	2·80	3·30	2·55	3·65

The composition of the gas (by volume), taken over two hours, was as follows :—

1909.	Carbon Dioxide.	Carbon Monoxide.	Hydrogen.	Nitrogen.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Feb. 4 . . .	10·80	29·90	1·40	57·90
„ 9 . . .	10·50	30·50	1·20	57·80
„ 10 . . .	10·30	30·50	0·90	58·30
„ 11 . . .	9·00	31·50	1·20	58·30
„ 12 . . .	9·5	31·2	1·0	58·30
„ 13 . . .	10·0	30·9	0·9	58·2
„ 15 . . .	9·5	30·8	1·1	58·6
„ 16 . . .	9·5	31·2	1·1	58·2
„ 17 . . .	9·0	31·5	1·3	58·2
„ 18 . . .	8·9	32·1	1·1	57·9
„ 20 . . .	8·3	32·1	1·4	58·2
„ 21 . . .	10·0	30·2	1·1	58·7
„ 22 . . .	9·5	31·7	1·5	57·3
„ 23 . . .	10·0	30·5	1·1	58·4
„ 24 . . .	9·5	32·0	0·7	57·8
„ 25 . . .	9·5	30·5	1·3	58·7
„ 26 . . .	9·5	31·0	1·0	58·5
„ 28 . . .	10·0	31·0	1·0	58·0
Mar. 4 . . .	10·0	30·5	0·9	58·6
„ 5 . . .	9·7	31·2	1·1	58·0
„ 6 . . .	10·0	31·0	1·1	57·9
„ 8 . . .	9·5	30·2	1·5	58·8
„ 10 . . .	9·5	31·0	1·1	58·4
„ 11 . . .	9·5	30·5	0·9	59·1

*Average Gas Analysis.*

Twenty-three Samples.	Volume.	Weight.	Carbon.	Oxygen.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Carbon dioxide . . .	9.61	14.47	3.95	10.52
Carbon monoxide . . .	31.02	29.71	12.73	16.98
Hydrogen . . . . .	1.18	0.08	...	...
Nitrogen . . . . .	58.19	55.74	...	...
	100.00	100.00	16.68	27.50

Coke used . . . . .	22.08 cwt.
Less 10 per cent. ash, &c. . . . .	19.87 cwt. carbon.
Carbon in limestone (partially calcined) . . . . .	0.66
	20.53
Less carbon in pig . . . . .	0.60
Total carbon in gases . . . . .	19.93

*Gases per Ton of Iron.*

	Weight.	Carbon.	Oxygen.
	Per Cent.	Per Cent.	Per Cent.
Nitrogen . . . . .	66.60	...	...
Carbon dioxide . . . . .	17.29	4.72	12.57
Carbon monoxide . . . . .	35.50	15.21	20.29
Water in coke . . . . .	0.85	...	...
Hydrogen in moisture of blast . . . . .	0.06	...	...
	120.30	19.93	32.86

*Weight of Blast per Ton of Iron.*

	Cwt.
Nitrogen . . . . .	66.60
Oxygen . . . . .	19.88
Moisture . . . . .	0.58
	87.06

*Comparison of Oxygen.*

Total oxygen per ton of iron . . . . .	32.86
Oxygen by blast . . . . .	19.88
By moisture of blast . . . . .	0.52
By ore . . . . .	9.00
By limestone . . . . .	1.77
	31.17
Diff. = Exp. error = 32.86 - 31.17 . . . . .	= 1.69

*Heat Development and Absorption.*

	Cwts.	
Carbon in coke . . . . .	19·87	
Less carbon taken off by carbon in limestone . . . . .	0·66	
Leaving carbon burnt to CO . . . . .	19·21 × 2400	= 46,104 calories.
Carbon of this CO burnt to CO <sup>2</sup> . . . . .	4·72 × 5600	= 26,432 „
		<hr/> 72,536
Heat from blast = 87·06 × 788 × 0·237 . . . . .		= 16,259
Total calories from coke and blast . . . . .		<hr/> = 88,795

*Heat Absorption.*

Evaporation of water in coke . . . . .	0·85 × 540	= 459
Reduction of Fe <sub>2</sub> O <sub>3</sub> . . . . .	18·44 × 1,780	= 32,823
Carbon impregnation . . . . .	0·6 × 2,400	= 1,440
Expulsion of CO <sup>2</sup> from limestone . . . . .	5·52 × 370	= 2,042
Decomposition of CO <sup>2</sup> . . . . .	0·66 × 3,200	= 2,112
Decomposition of H <sub>2</sub> O in blast . . . . .	0·06 × 34,000	= 2,040
Reduction of P, S, Si . . . . .	<div style="display: inline-block; vertical-align: middle;"> <div style="display: inline-block; vertical-align: middle;"> <div style="display: inline-block; vertical-align: middle;">P 0·31 × 5,747</div>  <div style="display: inline-block; vertical-align: middle;">S 0·01 × 2,500</div>  <div style="display: inline-block; vertical-align: middle;">Si 0·55 × 8,000</div> </div> </div>	= 6,206
Fusion of pig iron . . . . .	20 × 330	= 6,600
Fusion of slag . . . . .	30 × 550	= 16,500
Carried off in gases . . . . .	120·3 × 0·24 × 378	= 10,914
		<hr/> 81,136
Heat developed . . . . .		88,795
Leaving for other requirements (tuyere water, radiation, &c.) . . . . .		<hr/> 7,659

The difference of 7659 calories for other purposes is about the average which was found left over when calculating gas samples at Clarence.

In conclusion, the author has to express his thanks to Sir Hugh Bell for allowing him to submit the results of this experiment to the members of the Iron and Steel Institute, and he is also indebted to Mr. Weldon Hanson, head chemist, and to Mr. E. D. Morgan, the engineer at Clarence Iron-works, for services rendered during the carrying out of the experiment.



## THE FUEL ECONOMY OF DRY BLAST AS INDICATED BY CALCULATIONS FROM EMPIRICAL DATA.

BY R. S. MOORE (LONDON).

THE author was associated with Mr. Greville Jones in making a test to determine the effect of uniform moisture.

The results of the test points strongly to the fact that the great heat saving of the Gayley dry blast must be due to its dryness. The theoretical explanations on this basis have not been supported by any actual experimental proof, and they have apparently been as much rejected as accepted.

The principal experimental proof which is lacking is data on the saving of fuel to be secured by adding heat to the

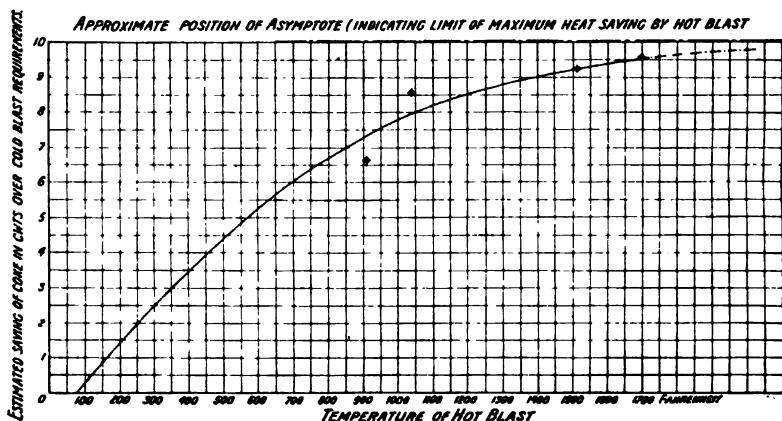


FIG. 1.—Curve of Relation between Temperature of Hot Blast and Estimated Saving in Coke.

bosh. In studying the conclusions suggested by the test, it occurred to the author that this hiatus is supplied by the results of experience with the Neilson hot blast.

Fig. 1 is a curve representing the relation between temperature of hot blast and coke saved based on cold-blast require-

ments, the data for the points from which this curve is plotted being taken from Sir Lowthian Bell's book on "The Principles of the Manufacture of Iron and Steel."

A curve which represents the variations of coke consumption with heat added to the blast, also represents the combined effect of all physical and chemical changes taking place in the blast-furnace, whether the heat changes have to do with carbon monoxide reduction, the carbon reduction, or the heat absorbed by the iron, the slag, or by heating stock. It is therefore a curve of practice rather than of theory, in so far as it is accurately plotted.

It is evident from the slope of the initial portion of the curve, that a saving of 1 cwt. of coke is obtained for approximately each  $100^{\circ}$  F. increase of blast temperature. The heat added in the blast per  $100^{\circ}$  per ton of iron is 276,000 British thermal units. 154,000 British thermal units are required per ton of iron to disintegrate 1 grain of moisture per cubic foot in the blast. This heat is therefore equivalent to  $154,000 \div 276,000 = 0.56$  cwt. on the initial portion of the curve.

But the saving in the upper portion of the curve is less than  $\frac{1}{2}$  cwt. per  $100^{\circ}$  F., and the question now arises, what portion of the curve applies to the heat necessary to disintegrate moisture? It is a well-known fact, that for the economical reduction of iron oxide in the blast-furnace, as large a proportion as possible must be reduced by carbon monoxide.

Now, as this reduction occurs most readily at about  $1100^{\circ}$ , and decreases rapidly at higher temperatures, and as the temperature of the stock entering the furnace soon approaches this point, it follows that a limit to the amount of heat which should escape in the gases rising from the bosh is soon reached. It was pointed out by Sir Lowthian Bell years ago, that the economy of the Neilson hot blast was due to the fact that adding heat to the blast enabled it to supply much of the heat necessary in the bosh to melt the iron and slag. The heat which was thus absorbed did not have to pass through the upper carbon monoxide reducing zone, thereby heating it and retarding the reduction.

Now, the heat which the iron and slag require is only about 18 per cent. of the total; it appears self-evident, therefore, that the fewer heat units which are added to the blast, the easier it is for the iron and slag to absorb them before they pass out of the bosh; but as the 18 per cent. is approached, more and more escape to the reduction zone. Therefore, removing the moisture before it enters the furnace is equivalent to utilising all the heat necessary to disintegrate it in melting the iron and fusing the slag. The economy to be expected from low moisture alone is therefore that represented by the initial portions of the curve, or 1 cwt. of coke for 100° F. temperature of blast, or, as pointed out before, 0.56 cwt. per grain of moisture per cubic foot.

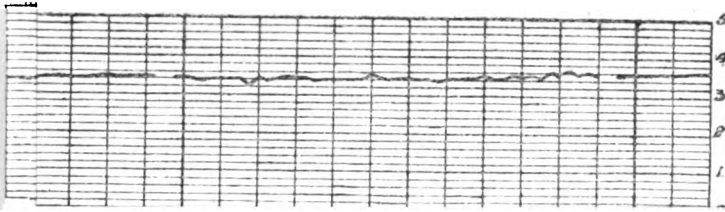
If 5 grains be taken as the average amount of moisture which can be eliminated, this would be equivalent to  $5 \times 0.56 = 2.8$  cwt.;  $2.8 \div 20 = 14$  per cent. of 20 cwt. per ton of iron.

About 2 grains of moisture were added to secure uniformity, and no gain or loss was found except a very slight lowering of the silica, indicating that the harmful effect of the 2 grains added was almost neutralised.

If it be assumed that the heat gain due to uniformity is equivalent to one-half of this, or to the effect of 1 grain, the foregoing considerations would account for a saving of about 17 per cent. of fuel for dry blast. It may be said that a saving of 2.8 cwt. on 28 cwt. coke consumption on cold-blast is not necessarily equivalent to a saving of 2.8 cwt. on 20 cwt. hot-blast consumption.

There must, of course, be some difference, but it is probably very slight, because, while under cold-blast consumption 40 per cent. more coke is burned than under hot-blast, 50 per cent. more ore is contained in the furnace under hot-blast conditions. Therefore, while there is less carbon monoxide generated, it acts on 50 per cent. more ore, and under better conditions of efficiency, namely lower temperature. The rate of increase of ore volume to coke volume is also approximately twice as great per cwt. of coke decrease at 20 cwt. hot-blast consumption as at 28 cwt. cold-blast consumption. The coke saving in the two cases should therefore be very closely similar.

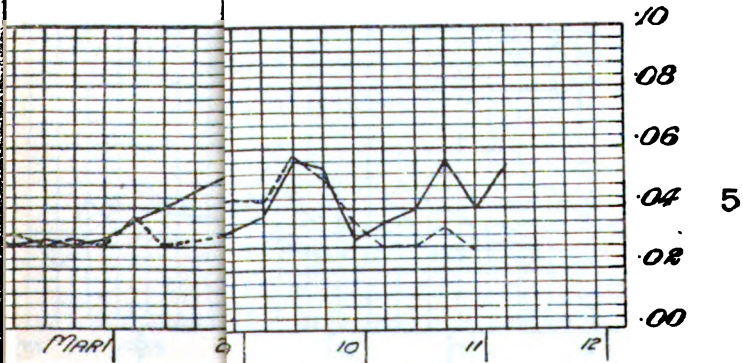
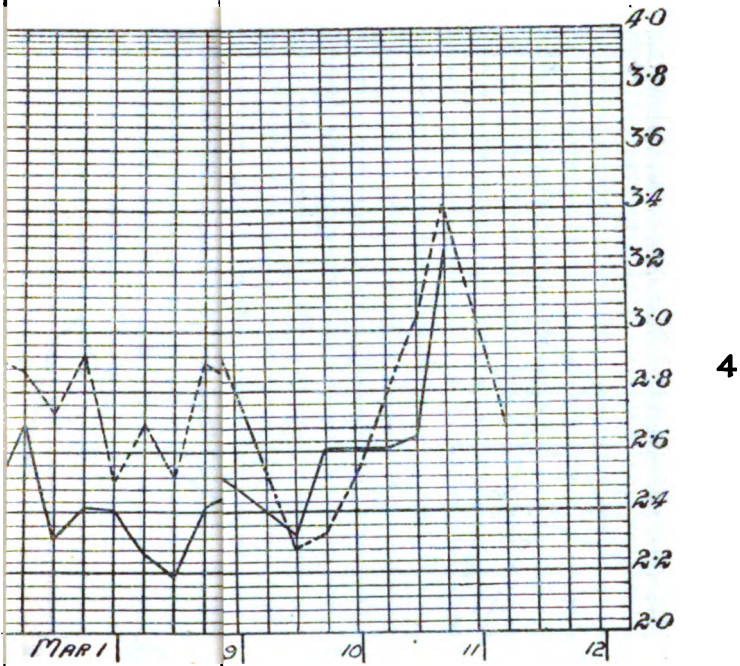
# PLATE VIII



1



PLATE IX





The author regrets that, in the limited time at his disposal, he has been unable to get reliable and full data for more points for the curve. The data is difficult to find, because all the figures for the curve must be for one furnace, operating in each case under the same conditions of ore, fuel, and fluxes. As it is, he trusts there is sufficient to allow of the present contribution finding acceptance as another interesting chapter of the story of the development of the Gayley dry-air blast.



*DISCUSSION.*

Mr J. E. STEAD, F.R.S., Member of Council, said that he had only one or two remarks to make, as he might have something to communicate to the Institute on the subject at a later date. He desired, however, to ask Mr. Greville Jones to tell them exactly the amount of steam used or the amount per ton of iron. The actual increase in coke was less than would be expected to occur by increasing the moisture.

Mr. COSMO JOHNS (Sheffield) said he welcomed that most interesting contribution of solid facts to the discussion of the cause of the economy that attended the use of desiccated air in blast-furnace practice. Since the important communications of Mr. Gayley giving his results, he might say that every metallurgist interested had been looking out for something that would enable them to formulate a theory that would explain the economy attained. The theoretical investigators had failed, for, after first insisting that the described economy was not possible, they later, when confronted with data that could not be ignored, put forward theories that were only consistent in that they all failed to explain the known facts. Clearly the problem was too complex for any explanation on purely theoretical grounds. One of the most important questions was whether absolute dryness was necessary for the attainment of the maximum economy. In other words, if the efficiency of the furnace were plotted against the degree of humidity in the blast, would the resulting curve be a smooth one, or would there be a break at some point short of the amount of desiccation insisted upon in Mr. Gayley's practice? He (Mr. Johns) was afraid that it would not be possible to reproduce the many complicated conditions of a blast-furnace in any laboratory experiments, and thus research work on a small scale could hardly be looked to, to supply the data necessary for determining the suggested curve. For that reason the present paper was very welcome as a contribution to the solution of that most interesting problem.

Mr. E. P. MARTIN, Past-President, said that, from the experience his firm had had at their Cardiff works, there was a very great saving in coke by the use of the Gayley system. At one time they had an idea that the system was being favoured by being applied to the best furnace, but they had had an opportunity of revising that opinion by applying it to the worst furnace, or what they considered to be the worst furnace. The relative saving was maintained in both cases.

Mr. E. H. SANITER (Rotherham) said he thought Mr. Greville Jones's paper had added very valuable information respecting economy. He did not quite agree, however, with the statement in the paper that there was no economy by levelling those peaks. It seemed to him (Mr. Saniter) that when they put more moisture through the blast-furnace, and did not use more coke, they were doing more work. If they had the figure

which Mr. Stead asked for, it would be possible to calculate from the extra steam which had been passed through the furnace how much coke had been used to decompose that steam; and the coke used for decomposing the steam would be the absolute economy obtained by uniformity. The question of uniformity had been one of the great arguments in that matter of dry blast. Part of the economy had been attributed to the reduced moisture and part of it to the uniformity. He thought that the information given by Mr. Greville Jones was very valuable when he dealt with the value of the uniformity independently of the value of the diminished moisture.

MR. J. H. HARRISON (Middlesbrough) said that if Mr. Greville Jones and his firm would be willing to make a further experiment, he thought that the subject of the paper would have more light thrown upon it. So far as he could see, it had been a matter of putting moisture into the blast during the whole of the period more or less, so that the blast taken right through, as Mr. Stead had pointed out, contained a greater amount of moisture than would otherwise have been in it if it had been taken from the atmosphere. Four grains was a good deal, particularly at a time of year when the temperature of the atmosphere was pretty high. Would it not be possible to reduce the moisture down to, say, 2 or  $2\frac{1}{2}$  grains per cubic foot, and keep it at that all the time, taking the winter months as an opportune time for that to be done? He thought that by simply using the cold water coming into the works it would be possible to keep the moisture down to 2 or  $2\frac{1}{2}$  grains per cubic foot continuously, and to run it regularly in the same way as had been done at 4 grains. That would be a further step in the way of elucidating the interesting problem as to where it was that all that saving of 17 per cent. came in. Mr. Greville Jones had shown that on 4 grains there was no saving, and that with 1 or  $1\frac{1}{2}$  grain there was a saving of 17 per cent. Presumably there would be a considerable gain if they could get the moisture down to about the point stated without any very great cost for apparatus. It might be worth while, in order to obtain the most economical result, to try to get to a point of, say, 2 or  $2\frac{1}{2}$  grains rather than to go the whole length, which was such an expensive business. At any rate, he thought it was worth consideration whether, now that Mr. Greville Jones had got the apparatus, he and his firm would be willing to make the experiment. The results would in all probability prove to be very valuable.

MR. A. K. REESE (Glamorganshire) said it appeared to him that the experiments described in the paper rather proved what Mr. Jones seemed to have concluded he had disproved. It was within the experience of every man who had operated blast-furnaces that to increase the moisture in the blast, whether by means of blowing steam into it or in other ways, meant that the economical operation of the blast-furnace would be interfered with and its fuel-consumption increased. The increase of moisture certainly did no good to the blast-furnace as they all knew, so that, under usual conditions, to increase the moisture in the blast would

mean that they would naturally expect poorer results than they would have got with the normal atmospheric moisture. Now, here they had a case in which they had as good results after increasing the moisture in the blast as they had before increasing it. It seemed to him that was a very clear indication of some benefit from the uniformity of the moisture, the added moisture being to obtain such uniformity. Surely there was no other way of explaining the fact that they had equally good results in both cases. He thought it might be said that they had better results, therefore, under the conditions of the experiment, than before, everything being considered, and it would lead him to conclude that the uniformity of the moisture had been a benefit in that furnace instead of no benefit at all, as Mr. Jones had concluded.

Comparing the results of the Cardiff blast-furnaces which were blown with dry air, and those of the South Chicago furnaces which had also been operated on dry air for some fifteen months or more, it was a curious fact that the benefits obtained in Cardiff with dry air had been practically the same as those at South Chicago. But whereas at Cardiff there was an average of  $2\frac{1}{2}$  grains of moisture actually removed from the blast, the reduction there being something like  $3\frac{1}{2}$  grains to 1 grain; in South Chicago the average removal of moisture was about 6 grains per cubic foot. It seemed to him that the only possible explanation of the similarity of the benefits derived in these two places must have been the uniformity of the moisture. There could be no other explanation. Of course, no doubt part of the benefits were due to the actual removal of the moisture. But here they had a case where over twice as much moisture was taken out in one place as in the other, and yet they had practically the same benefits. What could it be possibly due to excepting the more uniform operation of the furnace through the uniformity of the moisture, and, through the uniformity of the temperature of the dry blast, the uniformity of the oxygen in the blast? In other words, it was due to the uniformity of the quantity of oxidising agent in the air. That would lead them to the fact that uniformity certainly had a great deal to do with the benefits derived. Of course, one would naturally expect the benefits of uniformly low moisture to be much greater than uniformly high moisture, as part of the saving must be due to the actual removal of the water in the natural air. He thought that those experiments of Mr. Jones were certainly very interesting, and, he might say, very novel. He should say that Mr. Jones had displayed a great deal of courage in undertaking those experiments, for he had had the courage to put the moisture into his blast, whilst most ironmasters seemed to lack the courage to take it out. From his experience he was quite satisfied that, if they could have a little more courage and take it out, they would find that the uniformity had a good deal to do with it, and a good deal more than they had, at present, any idea of.

Mr. W. J. FOSTER (Walsall) said there was one very important point on which he would like to have some information. Mr. Greville Jones gave the efficiency of the blast-furnace tabulated in the form of calories. He wished to ask Mr. Greville Jones how he arrived at the result

that 32,832 calories were actually required to reduce sufficient oxide of iron to make one ton of pig, whereas the total calories were only represented by 88,795. In a similar way he would also apply the question to the whole system. He knew very well, of course, that those calculations were based on Sir Lowthian Bell's principle of calculating the efficiency of the blast-furnace. While he acknowledged that probably no other man had done more than Sir Lowthian Bell in attempting to arrive at the nature of blast-furnace reactions, he (Mr. Foster) was not satisfied with the method adopted to calculate the efficiency, and contended that Sir Lowthian Bell had left plenty of room for improvement in ascertaining the true nature of that process. He (Mr. Foster) had already written two papers for the Institute on the nature of blast-furnace reactions. The first, read in 1902, dealt chiefly with the physical and chemical properties of carbon in the hearth of the blast-furnace, while in 1904 he dealt briefly with efficiency. He had also contributed a paper to the Staffordshire Iron and Steel Institute in which he gave a diagram explaining—theoretically and practically—what could be expected in those days from the elimination of moisture from the blast, and consequently how to account for the saving due to the application of hot blast. He thought the paper read before the Staffordshire Iron and Steel Institute came pretty nearly to solving the problem of dry air. The experiment conducted by Mr. Greville Jones had, he thought, clearly proved that the saving in dry air was not due to the uniform moisture in the blast only, or at all events not to the extent claimed by other authors. At the same time it should be clearly understood that regularity was undoubtedly of vital importance throughout the whole cycle of blast-furnace operations.

Mr. LOUIS STERNE (London) said he had just received a cablegram from Mr. James Gayley. He (Mr. Sterne) desired to make a few remarks on the paper, but he would prefer to do so after the cable had been read.

The SECRETARY then read the following communication: "Mr. Greville Jones's experiments show he put more moisture in his blast with steam than was normally in the air at the time. Therefore it is to be expected that coke consumption on that furnace should be higher than it previously was on normal air. Mr. Jones took February in which to experiment, and charts show normal air moisture was very uniform. Therefore he did not increase the uniformity of moisture to any marked degree. Had he taken summer month when moisture would be higher and more irregular, he might have got more valuable data. His experiments indicate that uniformly high moisture is no better than irregular moisture. Slightly lower uniform low moisture and provision to engines of air supply uniform in temperature gives greatest economic results through the concentration of heat in the hearth and the uniform descent of uniform material into hearth. Mr. Moore's paper shows extraction of moisture has an equivalent heat value in the furnace. He shows a saving of practically 14 per cent. in coke consumption according to his calculations on elimination of

"five grains moisture. This is based on temperature equivalents with use of hot blast up to 900° Fahr. He further shows that as regards principle of coke consumption being lessened as temperature of hot blast increases, coke consumption will also be lessened in a certain proportion by use of dry blast, due to better operation of furnace, which latter is again due to greater heat concentration in bottom of furnace from more perfect general operation.—GAYLEY."

Mr. STERNE, resuming, said he had prepared some figures, and he could assure those present that they could be relied upon. They served to illustrate the great benefits to be derived commercially by the use of dry air blast, and were as follows :—

#### GAYLEY'S PATENT DRY AIR BLAST PROCESS.

*Savings by Dry Air Blast. Compiled by a Committee of the United States Steel Corporation.*

	\$	£	s.	d.
Saving in limestone through less coke used . . . . .	0.05	=	0	2½
Saving in flue dust * . . . . .	0.04	=	0	2
Through increased regularity of metal . . . . .	0.05	=	0	2½
Duration of lining can be increased 30 per cent. . . . .	0.06	=	0	3
Counting 10 per cent. increased product will reduce cost above material . . . . .	0.10	=	0	5
<b>Total . . . . .</b>	<b>0.30</b>	<b>=</b>	<b>1</b>	<b>3</b>
Saving in coke, 15 per cent. . . . .	...		...	...
Value of 10 per cent. increased in output . . . . .	...		...	...
<b>Total saving . . . . .</b>	...		...	...

In merchant furnaces the make of desired grade is increased 75 per cent.

#### GAYLEY'S PATENT DRY AIR BLAST PLANT.

*Erected in 1907 for Messrs. Guest, Keen & Nettlefolds, Ltd., at Dowlais Cardiff Works, by L. Sterne & Co., Ltd.*

Period.	Weekly Product. Tons.	Coke per Ton Iron. Pounds.
Average of first fifty weeks of blast on natural air . . . . .	2001	2278
With dry air blast, and operated for increase in output (average of five weeks) . . . . .	2530	1972
With dry air blast, and operated for economy of fuel (average of four weeks) . . . . .	2286	1857
Advantage of dry air for increased output—		Per Cent.
Increase in output . . . . .		26.4
Decrease in coke . . . . .		13.4
Advantage of dry air for decrease in coke consumption—		
Increase in output . . . . .		14.1
Decrease in coke . . . . .		18.4

The above data are given to show the elasticity of the dry air process as applicable to commercial conditions.

\* In iron used for steel making.

Every ironmaster could readily figure for himself the relative source of profits according to the capacity of the ore and the cost of coke in his own district. If one could increase the output of a furnace by the adoption of the Gayley dry air blast, only 15 per cent. on the average—and that was too conservative an estimate—there was not only a profit of 15 per cent. more on the output, but there were many collateral advantages incidental to the system which were shown in the figures relative to the practice at Cardiff. The decreased cost of the output was also an item of profit of considerable importance to the ironmaster. That increased output, in conjunction with the economy of fuel, could be easily calculated, and would show that it would recoup the entire outlay on the dry air blast plant, independent of the building, within eighteen to twenty-four months. With those manifest advantages to be derived from the adoption of the Gayley dry air blast, it was surprising that ironmasters should hesitate to install a plant which, beyond all question, proved to be such a profitable investment. In the United States the Gayley system of dry air blast had already been adopted for furnaces requiring over 1,000,000 cubic feet of air per minute. That result was mainly due to the investigations of the Committee of the United States Steel Corporation. Mr. Gayley had devoted considerable capital and many years of hard labour to the perfection of the system, and to him belonged the credit of the invention and its practical development. It constituted the greatest single advance in the iron industry since the introduction of hot blast.

Mr. J. HILL (Derby) pointed out that in spraying water into a furnace they must not forget they were spraying oxygen, and that was one of the chief factors.

Mr. T. B. ROGERSON (Glasgow) said he understood it was five or six years since the Carnegie Steel Company first undertook to dry air by the Gayley process. He understood at that time that they started with one furnace. The question he would like to ask was: How many furnaces had the Carnegie Steel Company now working on dry air? Had they increased the number, and if not, why had not they done so? He did not know whether Mr. Greville Jones or any one else present could tell him anything on that point.

Mr. REESE, in reply to the question put by Mr. Rogerson, said he understood the Steel Corporation had three furnaces at present in operation with dry air in South Chicago, and they were preparing plans for three more. In addition to those, he had also been told that they were preparing plans to equip twenty more furnaces with dry blast. When they were going to start them he did not know.

Mr. GREVILLE JONES, in reply, said that the answer to Mr. Stead's question was that the amount of steam added was 11·2 lbs. per ton of iron made. The diagram at the end of the paper showed that in some cases they added a grain or a grain and a half, and in other cases, when the

moisture was very heavy, the valve was shut down. With regard to Mr. Saniter's remarks there was no saving in the manufacture of pig iron. Pig iron was not any cheaper through the experiment than before the experiment. He did not think he had expressed any doubt that if there had been any saving at all it would have been due to the uniform dryness. He would consider Mr. Harrison's suggestion, but he was afraid it would be very difficult to reduce the moisture without putting down a dry air plant. As to Mr. Foster's point, he might say that they had been in the habit, long before he went to Clarence, of using those factors for the calculation of heat absorption in the blast-furnaces. If Mr. Foster had found out anything new of interest they would be very glad to go into the matter and see if those figures needed revising or not. Mr. Sterne had made a remark with regard to labour being reduced by the increased output on the blast-furnace. He had gone very carefully into those figures in the Cleveland district, and he did not know whether Mr. Sterne was aware that the workmen in the North of England were paid on every ton of iron they made. With regard to Mr. Rogerson's comment, he might say that the Canadians seemed to be going ahead with dry blast installation, and there seemed to be a number of orders on hand in the United States as well.

The PRESIDENT said he had much pleasure in moving a vote of thanks to Mr. Greville Jones and to Mr. Moore for the papers they had submitted to the meeting that day. He was sorry that Mr. Moore was unable to reply. There could be no doubt that, so far as blast-furnace practice was concerned, the question of the use of a dry air blast was of the utmost importance, and the solution of the problem which was presented to the ironmaster was no doubt a very urgent one. He could not help feeling that, as a result of the discussion, the definitive solution was still postponed. When Mr. Reese was speaking there was running through his (the President's) mind a saying of the late Mr. Walter Weldon, who opined that it took £10,000 and ten years to make a chemical experiment. He was sure that those of them who were engaged in the iron trade, and were accustomed to making experiments, would agree with Mr. Weldon, excepting that he had underestimated the cost. Ten years was a very limited period in which to complete an experiment, and he wished all the experiments with which he had been connected had cost as little as £10,000 apiece. It was not an easy matter to experiment on blast-furnaces, nor was it cheap. His firm had been very glad to put a furnace at the disposal of Mr. Moore and Mr. Greville Jones, but he could not help agreeing with the observations which fell from Mr. Reese as to the desirability of some further experiments in that direction. At the same time the testimony that had been received from South Wales and elsewhere certainly appeared to indicate that, in many cases at all events, a very considerable amount of economy had been obtained. As the elucidation of such problems constituted the *raison d'être* of their presence there, he thought it might be concluded that the ironmasters of Great Britain and of the world would not fail to continue their investigations so as to obtain a final solution

of that very interesting problem. They had to thank those two gentlemen for bringing it before them in somewhat a novel shape, and in a form which the discussion had proved to have been very interesting. He moved that the best thanks of the Institute be accorded the authors for their papers.

Carried by acclamation.

### CORRESPONDENCE.

Mr. C. H. RIDSDALE (Middlesbrough) wrote that Mr. Moore's explanation was, no doubt, substantially correct. It indicated that the reason for the great effect of moisture in blast was that its introduction caused a loss of heat in the hearth, and that diminished the temperature at the very part of the furnace which was most sensitive and where it was most desirable that a high temperature should be attained. That point had, no doubt, not been sufficiently kept in view in those theoretical explanations which failed to account for more than part of the saving by dry blast, but which saving—none the less—theory showed, if that was borne in mind.

Some ten years ago he (Mr. Ridsdale) had, whilst working some blast-furnaces, been struck by the disproportionately large effect which, in practice, various causes—although at first sight trivial—that affected the temperature of the hearth had on grade and coke consumption. Amongst those was the introduction of water at the tuyeres—whether through leakage or as moisture in the blast. To clear up the point he had made very careful balance-sheets of heat received and consumed by blast-furnaces at various coke consumptions ranging from 21 to 30 cwts., and the study of those sheets went far to account for the disproportionate effects. As the data so obtained had since, from observation, constantly proved to be reliable, he thought it might, in that connection, be of interest to refer to them, particularly as to the introduction of water into the hearth.

They showed very clearly that—however high the coke consumption—of the whole coke charged, most of the heat yielded went in doing “dead” work; that was work the effect of which was not apparent (such as effecting chemical change, heating escaping gases, &c.), and that it was only the small balance over what was necessary for that purpose, namely, a very small excess of heat, which, once the “dead” requirements were satisfied, produced the effects noticed on grade, or its equivalent, coke consumption, for it should be remembered that quality of the iron, by which coke consumption was regulated, was governed not only by the quantity of heat supplied to the furnace, but also by the intensity of heat, or temperature attained in the hearth. The effects of small variations of heat available were thus accentuated when they occurred in the hearth. Thus—to take an instance in which the coke consumption was near to Mr. Moore's—

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namely, 27 cwts.; of that the heat produced by 21 cwts. was used up for purposes other than the fusion of slag and pig, and only that from 6 cwts. was used in the hearth for those purposes. In that case his (Mr. Ridsdale's) figures had led him to a very similar conclusion to that given by Mr. Moore, as he found that a change of grade (amounting to a drop of silicon 0.5 per cent., phosphorus 0.05 per cent., and manganese 0.9 per cent.) was effected on 1 ton of iron by half a cwt. of coke, or the introduction of water only amounting to 1.14 grain per cubic foot of blast. That—on a 28-cwt. consumption, as in Mr. Moore's instance—amounted to 1.10 grain, requiring half a cwt. of extra coke—this being through a decrease of dryness alone—which, for a check arrived at by independent means, was pretty near, and confirmed the general argument.

It would be seen from the foregoing that an increase of 3 grains of water in the blast would abstract heat requiring, to replace it, an extra  $1\frac{1}{2}$  cwt. of coke, charging at the top, but which, however, was about 21 per cent. of the total heat used in the hearth where intensity was required and the final effects on the iron were produced. That gave a very different impression of its effect to merely regarding the total coke charged. As regarded the proportion of heat per unit of coke charged which was actually developed in the hearth, it should be borne in mind that, too, was always low relatively to the total heat developed from it in the whole furnace. In the case in question it was only 49 per cent., and if a deficiency of heat occurred through its abstraction from the hearth, by the introduction of water, the extra coke charged (rendered necessary to make good such deficiency) only gave a similarly poor yield. Indeed it should be borne in mind that even of extra coke charged beyond that used up for ordinary requirements, the full effect was not all felt in the hearth. It required extra blast to burn it, and hence introduced more water, had to heat more gases, yielded more ash (which in turn required more flux) and produced more slag. In fact, in the case in question, about 25 per cent. of the heat actually obtained from the extra coke charged was used up in satisfying its own requirements, so that only 75 per cent. was obtained in the hearth.

The above explained why abstraction of heat from the hearth told so heavily on coke consumption. With regard to the further benefit from uniformity, every one who had worked furnaces knew that the keynote to successful working was uniformity of conditions, and that irregularities of all kinds were prejudicial, so if the directly measurable effect of addition of water was so great, it was easy to understand that the less easily measurable effect of variation in quantity would have a correspondingly marked effect. Mr. Greville Jones' paper seemed to show that the gain in regularity of water content was sufficient to counterbalance the detriment of the addition of a certain amount (equal to about 0.5 grain per cubic foot) of blast.

## ARTIFICIAL MAGNETIC OXIDE OF IRON.

By F. J. R. CARULLA, F.C.S. (DERBY).

ONE more process, it would seem, must be added to the number of those that have had their inception in England, but which have been developed abroad. The Wülfing process, introduced from Germany, for the manufacture of a blue-black oxide of iron colour from ferrous liquors of which an account was given to this Institute at the recent Vienna Meeting,\* finds its parallel in a discovery of Dr. William Gregory which appears to have been lost sight of. It, however, in no way detracts from the merit of Dr. Wülfing nor from the value of the existing patents.

Gregory observed,† that when a solution of protosulphate of iron is divided into two equal parts, one of which is peroxidised, then mixed with the other, and precipitated by ammonia at a boiling heat, a black oxide is obtained, which does not attract oxygen in drying, and is highly magnetic. Its composition, he continues, must be  $2\text{FeO} + \text{Fe}_2\text{O}_3$ ; as the two solutions contain equal quantities of iron; and suggests that it may occur native as a variety of magnetic iron ore.‡

The above observation of Gregory's is not usually to be found in the small handbooks of chemistry excepting his own, wherein he has the following paragraph worthy of quotation in full:—

*"Magnetic Oxide of Iron.*—This oxide is the native magnet or loadstone, which is a heavy black mineral strongly attracting iron filings or steel. It is believed to be composed of pro-

\* *Journal of the Iron and Steel Institute*, 1907, No. III. p. 204.

† "Elements of Chemistry," by Edward Turner, 7th Ed., edited by Justus Liebig and William Gregory, London, 1842, p. 431.

‡ The magnetic iron ore from Rosedale, analysed by Pattinson, contains the ferric and the ferrous oxides approximately in the proportion to form  $\text{Fe}_4\text{O}_6$ . See Watt's "Dictionary of Chemistry," 1865, vol. iii. p. 337.

toxide and peroxide, and the native magnet is generally supposed to be  $\text{Fe}_3\text{O}_4 = \text{FeO} + \text{Fe}_2\text{O}_3$ . There is reason, however, to believe that another kind of magnetic oxide exists, which is  $\text{Fe}_4\text{O}_5 = 2\text{FeO} + \text{Fe}_2\text{O}_3$ . At all events, both of these compounds may be formed artificially, and both are magnetic as well as permanent, not absorbing oxygen or passing into peroxide. To prepare the former, take two parts of green vitriol; dissolve it in water and convert it into persulphate by boiling with nitric acid; then mix the solution with the solution of one part of the unaltered green vitriol, and precipitate the hot liquid by ammonia. A green precipitate falls which is to be washed and dried. The second magnetic oxide is prepared in the same way, only converting into persulphate one part of green vitriol instead of two parts. The precipitate is black if made in the liquid while hot. It is evident that in the latter case the quantity of iron, in the forms of protoxide and of peroxide, will be equal; in the former, the quantity of iron in the peroxide will be double that in the protoxide, so as to yield the above formulæ."\*

The paucity of information referred to may account for Gregory's observation not having found industrial application until recent years, and where the reaction is mentioned in one of the larger manuals it would rather deter one from attempting it on a big scale.

Thus it is stated that the hydrated magnetic oxide may be prepared by dividing an aqueous solution of sulphate of iron into three equal parts, peroxidising two of these with nitric acid, adding the other, and pouring the mixture, with frequent stirring, into an excess of solution of ammonia; if the operation were reversed, and the ammonia added to the mixture, the sesquioxide would be first precipitated, then the protoxide, so that a mixture and not a combination of the two would be obtained.†

It will be noticed that this is quite opposite to the experience of Gregory, who adds the ammonia to the mixed liquors. But however the matter may be regarded

\* "A Handbook of Inorganic Chemistry," by Wm. Gregory, 3rd Ed., 1853, p. 214.

† Abel and Bloxam, "Handbook of Chemistry," 2nd Ed., London, 1858, p. 400.

the conditions of the Wülfing process have removed all doubt, for by the application of heat and pressure after precipitation, the desired combination is obtained, as is evident from the magnetic character of the product. A mere mixture of  $\text{FeO}$  and  $\text{Fe}_2\text{O}_3$  would have no such property.

And here may be considered the fact that any of the black oxide obtained by this process is magnetic. The operation in actual practice is conducted by adding a portion of the ammonia to the ferrous liquor, which in Derby is the chloride, thus producing the lower hydrated oxide. By blowing air through the mass this lower oxide  $\text{FeO}$  is oxidised to the higher state  $\text{Fe}_2\text{O}_3$ . The rest of the ammonia is then added, sufficient to effect complete decomposition of the ferrous salt, and combination of the two oxides is brought about, as above stated, by means of heat and steam or air pressure, dehydration being at the same time effected.

It will be obvious that a mathematically exact division of the ammonia is practically impossible, as is also the exact peroxidation by means of air of the first precipitated portion of the oxide. The resulting final product will therefore contain different proportions of  $\text{FeO}$  and  $\text{Fe}_2\text{O}_3$  in every charge, a matter, however, of no practical significance when the process has been got into fair working order, the differences then not being great. The fact nevertheless makes the name ferroso-ferric oxide a peculiarly appropriate one if Gmelin's definition is accepted for these bodies, viz. those oxides of iron which contain more oxygen than the protoxide and less than the sesquioxide in various proportions.\*

Nevertheless there is ground for believing that, generally speaking, combination occurs only between  $\text{FeO}$  and  $\text{Fe}_2\text{O}_3$  to form  $\text{Fe}_3\text{O}_4$ , and that any excess of  $\text{Fe}_2\text{O}_3$  remains in admixture as such. The reason for this opinion is that it is possible to obtain a great variety of colours quite as one might expect from mixtures containing varying quantities of the black magnetic oxide and of the highly coloured ferric oxide, as is shown in the annexed table, which gives the results of analyses of the first fifteen charges of the magnetic oxide produced

\* Gmelin's "Chemistry," vol. v. p. 190.

at Derby whilst apprenticeship to the process was being served.

*Formulae of Charges.*

No. of Charge.	Ferroso-ferric Formula.		Magnetic Formula.		Proportion of Magnetic to Ferric Units.	Colour.
	FeO Units.	Fe <sub>2</sub> O <sub>3</sub> Units.	Fe <sub>3</sub> O <sub>4</sub> Units.	Fe <sub>2</sub> O <sub>3</sub> Units.		
1	5	7	5	2	2·5	Black.
2	7	9	7	2	3·5	Black.
3	4	5	4	1	4·0	Black.
4	4	5	4	1	4·0	Blue black.
5	11	20	11	9	1·22	Brown.
6	7	10	7	3	2·33	Brown black.
7	7	10	7	3	2·33	Blue.
8	8	9	8	1	8·0	Blue black.
9	8	9	8	1	8·0	Black.
10	8	9	8	1	8·0	Black.
11	5	8	5	3	1·66	Green.
12	3	4	3	1	3·0	Brown black.
13	7	8	7	1	7·0	Black.
14	6	7	6	1	6·0	Greenish black.
15	3	4	3	1	3·0	Blue.
Dr. W.'s.	5	6	5	1	5·0	Blue black.

In the table the various values are derived from the proportion of ferric to ferrous oxide found in the different samples, columns 2 and 3 giving the ferroso-ferric formula; thus charge No. 1 would be  $5\text{FeO} + 7\text{Fe}_2\text{O}_3$ . It is obvious, however, that this formula can rapidly be transformed into the magnetic formula  $5\text{Fe}_3\text{O}_4 + 2\text{Fe}_2\text{O}_3$ —that is to say, the one more likely to be correct—by simply taking the units of FeO as units of  $\text{Fe}_3\text{O}_4$ , subtracting these from the units of  $\text{Fe}_2\text{O}_3$ , and regarding this remainder as peroxide in admixture. These numbers are given in columns 4 and 5. This view seems to quite accord with the analyses of magnetites in Dr. Stutzer's valuable table.\*

Column 6 gives the proportion of magnetic to ferric units, and it will be seen by the last column that where the magnetic units largely preponderate the colour is usually a decided black. Where the ferric units approximate in number to the magnetic the change from black is very decided, as in Nos. 5 and 11.

\* *Journal of the Iron and Steel Institute*, 1907, No. II. p. 178.

The last sample in the table, marked Dr. Wülfing's, is a normal product of the process.

It may be mentioned that although the variations obtained may militate against the colour, as a black, they in no way injure it as a protective medium for paint purposes,  $\text{Fe}_2\text{O}_3$  being quite stable.

It is from this point of view—that is, from its possible instability—that  $\text{Fe}_4\text{O}_6$  might be thought to be a less desirable body to aim for in the process than  $\text{Fe}_3\text{O}_4$ . It is easy to conceive of  $\text{Fe}_4\text{O}_6$  as a tertiary product obtained by the combination of  $\text{Fe}_3\text{O}_4$  with  $\text{FeO}$ , in which case the ferrous oxide might be more lightly held than is the case in  $\text{Fe}_3\text{O}_4$ . If this were the case decomposition would more readily set in with  $\text{Fe}_4\text{O}_6$  than with  $\text{Fe}_3\text{O}_4$ .

This may well be, however, an erroneous conjecture, for it will be found that whereas some of the samples, for the purpose of analysis, dissolve in acid \* with the greatest ease, now and then one comes across an intractable body most difficult of solution. May it not be that in this case  $\text{Fe}_4\text{O}_6$  is the body so resistant to chemical action?

Charges Nos. 11 and 15 were of this character.

It may be well to recapitulate, and possibly make more clear, the points that it is desired to emphasise in the above remarks, although Dr. Wülfing worked out the industrial manufacture of the material from waste liquors—no small merit.

First, that to William Gregory of Edinburgh must be assigned the discovery of the artificial production of magnetic oxide of iron. Of this there can be no doubt, as what seems to be the earliest notice of it is found in a book of which Liebig was co-editor and Gregory gets full credit for it.

Secondly, that there are grounds for believing that magnetic oxide of iron made by the above process is either  $\text{Fe}_3\text{O}_4$  or  $\text{Fe}_4\text{O}_6$ , and that any variation from these formulæ is due to admixture of  $\text{Fe}_2\text{O}_3$ .

Thirdly, that to say whether the main portion of any sample is  $\text{Fe}_3\text{O}_4$  or  $\text{Fe}_4\text{O}_6$  is not a matter that can be asserted with certainty, although there are indications that

\* 0.5 gram of the magnetic oxide is dropped into a nearly boiling hot mixture of 15 cubic centimetres oil of vitriol and 50 cubic centimetres distilled water.

two distinct bodies exist in different samples, one of these being most difficult of solution. This is a matter well worthy the attention of some competent investigator to whom the subject may appeal.

Fourthly, that notwithstanding those difficulties that all beginners are sure to encounter, the product is difficult to spoil in the making, except as regards colour, and the operator can soon attain to the production of a commercially uniform article.

Finally, it may be added that the protective character of this magnetic oxide of iron is most marked. Just as the Bower Barff coating and the film on Russian sheet iron, both magnetic, afford protection to iron surfaces, so does this product when laid on in the form of paint.

The action that takes place through the localisation of scale on iron plates must not be thought to militate against the use of a magnetic iron paint. It might as well be argued that because a hot ember will burn a hole in the flesh, therefore diffused warmth must also be harmful.

The great protective value of what one may be allowed to call the Gregory-Wülfing magnetic oxide of iron paint is acknowledged by all who have had any experience of it.

*DISCUSSION.*

Professor TURNER said that the author of the paper had drawn their attention to the interesting fact that oxides of iron might remain magnetic in properties, and still be called magnetic oxide of iron, although they varied considerably from the formula  $\text{Fe}_3\text{O}_4$ . He remembered when he was a demonstrator of chemistry they used to prepare magnetic oxide of iron, and the properties of that oxide were shown in a very simple way to prove that it was really magnetic oxide. When the ferrous and ferric solutions had been mixed, heated to boiling, and the solution of ammonia had been added, the solution was then poured into a tall glass jar nearly filled with water, and allowed to subside. On the outside of that jar, and about half-way up, a magnet was placed. The result was that the particles of magnetic oxide formed a fringe or beard near the pole of the magnet against the side of the glass. His experience was that they could vary the proportion of ferric oxide considerably and still obtain a magnetic product. Those who had dealt with magnetic iron ores knew, of course, that there was an immense variation in composition. As an example, the ores of the Lake Superior district might be cited. They got some ores which were perfectly pure hæmatites; they got some ores which were magnetites, and they got a large number of ores of intermediate composition. A short time ago he had an ore from Brazil for analysis which was practically a magnetite, and yet the proportion of ferrous oxide was extremely small. By analysis it was nearly hæmatite, but all its other properties were those of magnetite. A small quantity of ferrous oxide was sufficient to impart many of the properties of magnetic oxide to an ore or to a material such as that to which Mr. Carulla had drawn their attention.

Mr. F. J. R. CARULLA (Derby), in reply, said he had to thank Professor Turner for giving so interesting an account of the magnetic properties of the solid precipitate. As a matter of fact, if the solid were dried and put on a piece of paper with a magnet underneath, they would get a magnetic field, and it scarcely mattered, in regard to its magnetic character, how the proportions of the two oxides varied so long as they made the material by that process, as Professor Turner had explained. An important application of Professor Turner's remarks was connected with the fact that structural ironwork became endowed with magnetic activity, as was observed by Scoresby, by the mere act of being put together by riveting and hammering. That extremely high development of the quality of retentive magnetism\* would be added to in modern times by the frequent use of powerful magnets that acted as cranes in fitting shops. When a coat of the Gregory-Wülffing paint in the liquid form was applied to such a structure, it would be obvious that just as in the experiment described by Professor Turner, an attraction would be

\* Scoresby, "Magnetical Investigations," vol. ii. p. 331, quoted in "The Life," &c., by R. E. S. Jackson.



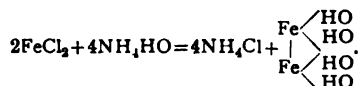
exerted on the particles of magnetic oxide in the paint by the iron that was being covered. Those particles would go up close to the iron surface, thus producing a most effective protection against rust and corrosion, that protection being further increased by the layer of linseed oil used as a vehicle which was in some measure set free on the outside surface of the coat of paint. That coat of oil as it dried and became oxidised by the action of the air gave rise to a very fine varnish-like covering, which was very characteristic of the magnetic oxide paint made with material obtained by the Wülfing process, and increased its protective power.

The PRESIDENT moved that the best thanks of the members be given to Mr. Carulla for his interesting paper. The Institute would recollect that at the May meeting an interesting discussion arose on the question of corrosion, and the matter was one of very considerable urgency now that iron and steel were coming so largely into constructional work. Anything that rendered those materials less liable to attack when exposed to atmospheric influence must be of very great value. It was well, therefore, that the attention of the Institute should be continually directed to the solution of questions in connection with the protection of iron. They had to thank Mr. Carulla for bringing the matter before them.

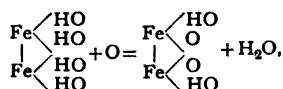
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### CORRESPONDENCE.

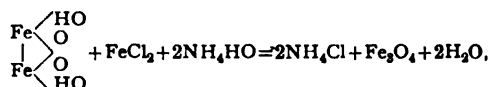
Dr. C. F. WÜLFING (Hönnigen-on-Rhine) wrote that the theoretical part of the process was, in his opinion, as follows: Ferrous chloride liquors with ammonia gave first a white-bluish precipitate, the reaction being—



The hydrated oxide became further oxidised with the oxygen from the air blast—



and this formed the yellow precipitate. The remainder of the ferrous chloride, plus the further ammonia added, then acted in the following manner:—



producing the black magnetic oxide. He believed that formula re-

presented the real working of the process. With regard to the practical application there could be no question of the value of the black oxide as a protective paint. It had had a good trial for seven years. Its manufacture on a small scale was due to the want of raw material, ferrous chloride liquors being used for other purposes, such, for example, as making barium chloride.

If oxidation of the yellow precipitate proceeded too far, it would turn green at a subsequent stage of the process. In the table the author stated that charge No. 11, with  $\text{FeO}$  units 5, and  $\text{Fe}_2\text{O}_3$  units 8, was green. It was not obvious with that composition why the product should be of that colour.

Mr. CARULLA wrote, in reply, that he desired to thank Dr. Wülffing for his view of the reaction that took place on the addition of the second lot of ammonia, as he showed how  $\text{Fe}_2\text{O}_3$  might become  $\text{Fe}_3\text{O}_4$  without  $\text{FeO}$  being separated in the process—an interesting point. It was quite likely that ferrous liquors might become scarce, as so many minds were at work on their utilisation, but that was a matter that must create a feeling of satisfaction in those whose business it was to prevent the pollution of rivers. The Wülffing process certainly beat every other in that respect, for every ounce of the material was used up, and there was nothing left to create a nuisance. As regards the question of colour raised by Dr. Wülffing, he could only say that charge No. 11 happened to be one of those difficult of solution in acid. It therefore might be one in which the mystery attaching to  $\text{Fe}_3\text{O}_4$  played an important part. The investigation of that body, including its separation in a pure form and absolute means of identification were matters that might well engage the attention of some research chemist of ability.

## THE ACTION OF AIR AND STEAM ON PURE IRON.

BY J. NEWTON FRIEND, PH.D., M.SC. (DARLINGTON).

THE whole subject of the corrosion of iron is one of great importance, both from a commercial and a purely scientific point of view. The desirability of pursuing further research upon it can therefore be scarcely exaggerated, until the numerous problems connected therewith have met with satisfactory solution.

In a recent communication to this Journal\* I have dealt fully with the action of air, water, and steam upon various forms of iron at temperatures not exceeding 100° C., and mentioned that experiments were in progress with the object of determining their action at higher temperatures. As the results obtained have reached the stage at which they can be safely discussed, it seemed advisable to give them publication at this date.

The iron used in this research was in the form of thin foil, which analysis showed to contain 99.9 per cent. of the pure metal.

### ACTION OF ORDINARY AIR ON IRON.

It is well known that when iron is heated in air it soon becomes tarnished, and the particular shade which the iron assumes gives a rough indication of the temperature. In order to compare the action of ordinary, moisture-laden air on pure iron with that of perfectly dry air and of steam, each at varying temperatures, the following experiments were performed:—

A tube, sealed at one end and containing a bright strip of iron foil, was immersed in an oil bath and maintained at

\* *Journal of the Iron and Steel Institute*, 1908, No. 11, p. 5.

100° C. for five hours. At the end of this time no alteration in the appearance of the iron could be detected. The temperature was now raised to 150° C. for a further period of five hours. Even after this treatment it was almost impossible to decide by mere observation whether or not the surface of the metal was tarnished, for the action was so slight.

A fresh strip was now heated to 220° C. in a similar manner, but in twenty minutes a slight straw tint developed, which became more pronounced as the heating was prolonged.

At higher temperatures the oxidation of the iron was much more rapid, and an almost momentary immersion in a lead bath at 350° C. sufficed to produce a clear blue tint.

#### ACTION OF PERFECTLY DRY AIR UPON IRON.

In view of the fact that H. Brereton Baker has frequently drawn attention to the influence exerted by minute traces of water-vapour on certain reactions, it was interesting to inquire whether or no pure iron would undergo oxidation on exposure to air at different temperatures dried over phosphorus pentoxide. The following results were obtained:—

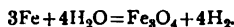
1. A tube, containing a strip of iron, about 60 millimetres long and 4 millimetres wide, separated from some phosphorus pentoxide by a loose plug of glass wool, was sealed. After the lapse of four months the end containing the iron was immersed in an oil bath at 190° C. for thirty minutes. As the change produced was exceedingly slight, the temperature was raised to 220° C. After the expiration of a second half-hour, the iron had assumed a light straw tint.

2. Two tubes similar to the above, one of which had been kept for three months and the other six, were plunged into a bath of molten lead at a temperature of 350° C. In a few moments the iron had assumed a bright blue colour.

We thus see that the entire absence of moisture will not prevent the oxidation of pure iron at temperatures of about 200° C. and upwards. These experiments are therefore being continued in order to include a wider range of observation.

## ACTION OF STEAM ON IRON.

For many years chemists have been familiar with the fact that, when steam is passed over heated iron, hydrogen gas is set free and hammer-scale, or magnetic oxide of iron, remains behind. The equation usually assigned to this reaction is:—



In my previous paper \* attention has been drawn to the fact that a mixture of pure steam and air may be passed over

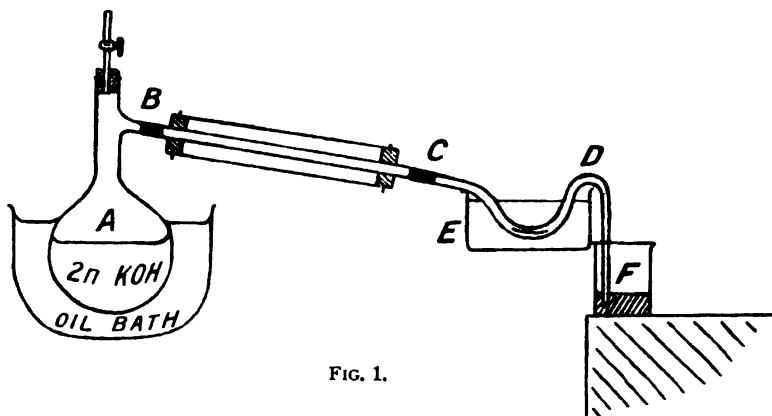


FIG. 1.

pure iron at  $100^\circ \text{C}$ . without producing any visible effect. The following experiments were therefore undertaken with the object of determining if pure,  $\text{CO}_2$ -free steam has any action upon pure iron at temperatures above  $100^\circ \text{C}$ ., and if so, at what temperature that action begins:—

*Temperature Range,  $100^\circ$  to  $250^\circ \text{C}$ .*—The apparatus used in these experiments is shown in the figure. The distilling flask A, of 500 cubic centimetres capacity, contained a 2-normal solution of potassium hydroxide, and was immersed in an oil bath, the temperature of which was maintained at approximately  $125^\circ \text{C}$ . In order to prevent bumping, the

\* *Op. cit.*, p. 21.

level of the potash solution was kept slightly lower than that of the oil in the bath,\* and small pieces of capillary tubing, sealed at one end, were dropped into A at the beginning of each experiment. It was found that, by adopting these precautions, a steady ebullition of the potash could be secured without the manifestation of any tendency to bump. The glass condenser BC was, in the later experiments, fused on to A at B, and connected with the glass tube CD by means of a short piece of rubber tubing. The free ends of the tubes at C were filed to fit one another, in the manner indicated by Bone and Coward,† so as to make a tight joint.

At the beginning of the experiment a strip of iron foil, 3 centimetres long, was put into CD, together with a few drops of potash solution to remove any adhering carbon dioxide. A was now raised to boiling point, and the steam condensing in BC washed the potash away from CD. When the water escaping from the open end F showed no alkalinity to phenol phthalein, F was closed with a mercury seal, the condenser BC allowed to run dry, and the oil bath E heated to various temperatures, not exceeding  $250^{\circ}\text{C}$ . After half-an-hour's exposure to the action of the steam at any one temperature the experiment was stopped by cooling A and allowing a solution of potassium hydroxide to be sucked up through F into CD.

In no case was the iron found to be appreciably tarnished. Temperature range,  $300^{\circ}$  to  $600^{\circ}\text{C}$ .

1. IN COPPER TUBES.—At first BC and CD were made of copper, whilst the oil in E was replaced by lead, the temperature of which was determined by means of a platinum resistance thermometer enclosed in a silica tube. The india-rubber joint at C was prevented from perishing with the heat by a loose wrapping of filter-paper kept moistened by a slow stream of water. The experiments were carried out in a manner precisely similar to that detailed above, save that before each fresh experiment CD was heated in a current of pure hydrogen gas to reduce any oxide. The following results were obtained:—

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\* See Friend, *op. cit.*, p. 14.

† *Transactions of the Chemical Society*, 1908, vol. xciii, p. 1984.

*Experiment I.*—Four strips of foil, from 2 to 3 centimetres long, were heated thirty minutes at  $330^{\circ}$  C. The strips remained quite bright, but each was attacked locally at about four different places—presumably where they had lain in contact with each other.

*Experiment II.*—One strip of foil was heated for twenty minutes at  $445^{\circ}$  C. The metal was decidedly tarnished.

*Experiment III.*—A strip of foil was heated for thirty minutes at  $520^{\circ}$  C. The metal was thoroughly attacked.

It would appear from these experiments that pure iron is attacked by pure steam at some temperature intermediate between  $330^{\circ}$  and  $445^{\circ}$  C. To arrive at a more accurate determination of the temperature, however, it was necessary to eliminate several possible errors:—

(i.) Caustic potash readily effects the oxidation of metallic copper in the presence of air, and the oxide thus produced is rapidly reduced by iron to cuprous oxide at temperatures near  $350^{\circ}$  C., with the simultaneous formation of iron oxide.\* It is clear, therefore, that during the initial stages of the experiment the inside of CD could scarcely fail to become oxidised, with the result that, on heating in the lead bath, the iron became slightly tarnished.

(ii.) Although the temperature of the bath could readily be determined, it was always possible that the temperature of the steam inside CD was slightly lower than this. As this is, unfortunately, an unknown factor, a correction could not be applied.

(iii.) It is well known that iron, in common with many other metals, possesses the property of absorbing quantities of different gases, such as the oxides of carbon, hydrogen, and nitrogen, and that the gases are evolved when the metal is heated.† It will be clear that these gases, even though present in very small quantity, might exert a disturbing effect upon the reaction under consideration.

(iv.) The most serious source of error, and one which it

\* A research into the nature of these reactions is already in progress.

† See Belloc, *Comptes Rendus*, vol. cxlv. p. 1280; Boudouard, *ibid.*, p. 1283; Sieverts, *Zeitschrift für physikalische Chemie*, vol. lx. p. 129.

was found impossible to obviate entirely, lay in the difficulty experienced in removing every trace of air from A and BC. This was rendered practically impossible, because a number of capillary tubes, sealed at one end, had to be introduced into the potash solution immediately before each experiment, in order to prevent bumping. The error thus introduced is, of course, slight. It has already been shown, however, that air attacks iron fairly rapidly at temperatures above  $200^{\circ}\text{C}$ . Consequently it cannot be expected that iron will remain absolutely untarnished, after exposure to steam containing traces of air, for any lengthened period. Bearing this in mind, however, it will be seen that the experiments described in the sequel, though but approximations to the truth, are not without value.

2. IN SILICA TUBES.—In order to eliminate the first two possible sources of error mentioned above, tubes of transparent silica were employed, of internal diameter 0.4 centimetre. The length of that part of CD actually immersed in the bath E was 23 centimetres, and the strips of iron (usually two in number) were placed at the opposite end to that by which the steam entered. The latter had therefore to pass through a considerable length of the heated tube before reaching the iron, and had thus a better opportunity of attaining to the temperature of the bath. Only such iron was used as had been previously heated to redness for ten hours in vacuo, whereby the greater part of its occluded gases would be expelled. To remove the air as completely as possible from A and BC, the potash was kept vigorously boiling for from one to two hours before the experiment was commenced, and the condenser allowed to run dry. The silica tube CD could not be filled with potash solution, however, as in the corresponding experiments with copper tubes, for the iron was rapidly tarnished by the action of the silica when all the alkali had been washed away, and before the passage of steam was commenced. CD was therefore filled with semi-normal ammonium hydroxide solution, which served to expel all the air from the tube. On connecting at C the steam rapidly expelled the ammonia and most of the water, and immersion in the bath, already at the desired temperature, served to vaporise rapidly



any remaining liquid. At the end of the experiment bath E was removed, and, after cooling to nearly  $100^{\circ}\text{C}$ ., CD was rapidly disconnected and plunged into a trough of dilute potash solution. This served at once to cool the tube and preserve the iron in contact with the silica. The metal was then removed and examined.

The following results were obtained:—

*Experiment I.*

Temperature of oil bath, E . . . . .	$292^{\circ}$ to $297^{\circ}\text{C}$ .
Passage of steam . . . . .	60 minutes.

Result: The metal was very slightly tarnished.

*Experiment II.*

Temperature of lead bath, E . . . . .	$330^{\circ}\text{C}$ .
Passage of steam . . . . .	60 minutes.

Result: Exactly the same as in Experiment I., save that in addition to the slight tarnishing, one strip had a small dark spot where the second strip had lain across it.

*Experiment III.*

Temperature of lead bath, E . . . . .	$350^{\circ}\text{C}$ .
Passage of steam . . . . .	60 minutes.

Result: The metal was a dark straw colour.

*Experiment IV.*

Temperature of lead bath, E . . . . .	$380^{\circ}$ to $390^{\circ}\text{C}$ .
Passage of steam . . . . .	60 minutes.

Result: The metal was very much darker, and thoroughly attacked.

Similar experiments were also performed for thirty minutes each at  $430^{\circ}$ ,  $450^{\circ}$ ,  $470^{\circ}$ ,  $510^{\circ}$ , and  $550^{\circ}\text{C}$ .; and for sixty minutes each at  $430^{\circ}$ ,  $470^{\circ}$ , and  $500^{\circ}\text{C}$ . In every case the metal was found to be thoroughly attacked.

Since the iron was only very slightly tarnished, but to an equal extent, in Experiments I. and II., although the temperature difference was above  $30^{\circ}\text{C}$ ., it seems reasonable to

conclude that the oxidation was caused by the traces of air in the apparatus, to which reference has already been made. Since these traces of air will remain practically constant in amount for any one apparatus, the increased oxidation observed in Experiment III. at  $350^{\circ}$  C. may be attributed to the action of the steam. As the temperature is raised to  $380^{\circ}$  C. and upwards, the corrosion becomes still more marked.

It appears, therefore, that steam begins to decompose in the presence of iron at some temperature intermediate between  $330^{\circ}$  and  $350^{\circ}$  C., and the action becomes evident at  $350^{\circ}$  in the course of an hour. It is highly improbable that any definite temperature could ever be fixed exactly at which the decomposition of steam might be said to begin. For at a certain temperature the amount of decomposition which could take place might be too small for detection in one hour, and yet in the course of several hours, days, or weeks be most pronounced. Furthermore, the physical condition of the iron and of the walls of the tubes through which the steam passes will probably exert a marked influence, for it is well known that gases are very susceptible to changes in this respect.

Another way of determining whether or not iron is attacked by steam at any particular temperature would be to observe if hydrogen gas escaped during the experiment. An apparatus is being devised with this object in view. The advantage is that the effect of traces of air would be negligible, but, owing to the solubility of hydrogen in water, the temperature at which this gas could be detected would be almost certainly above that at which the steam begins to undergo decomposition.

It may be of interest to place on record here the action of molten lead on silica. Repeated immersion of the latter for periods varying from thirty to sixty minutes in length, at temperatures ranging from  $330^{\circ}$  to  $450^{\circ}$  C., produced but little effect. On cooling the lead could be readily scraped off, leaving the tube nearly as transparent as before. After the prolonged immersion at  $500^{\circ}$  to  $600^{\circ}$  C., extending over several hours, to which the pyrometer tube was exposed, the lead was less readily removed. On scraping thoroughly and immersing

in nitric acid for several hours the tube became nearly clear again, though a slight milkiness still persisted. It will thus be seen that transparent silica tubes form an excellent protection for a pyrometer immersed in a lead bath—at any rate when the temperature does not exceed  $600^{\circ}\text{C}$ .

The results detailed above are capable of explanation in two ways:—

- (i.) We may assume, as is usually done, that the iron itself decomposes the steam at those temperatures at which corrosion takes place.
- (ii.) The reaction may be regarded as taking place in two stages, comprising, first, the dissociation of the steam; and, secondly, the union of the oxygen thus liberated with the metallic iron.

The former view is not easy to reconcile with the fact that hydrogen gas readily reduces the oxides of iron to the metallic condition—a reaction which is the direct reverse of that under discussion.

On the other hand, the second view \* explains the above anomaly, and is also in harmony with our knowledge of the dissociation pressures of oxygen in equilibrium with steam and oxide of iron.

Alfred Holt, jun.,† has recently attempted to determine the lowest temperature at which the dissociation of steam becomes a measurable quantity. He finds that at  $775^{\circ}\text{C}$ . very small volumes of electrolytic gas can be collected—a fact which proves that dissociation must begin at considerably lower temperatures. There can, therefore, be no objection to the assumption that at  $350^{\circ}\text{C}$ . steam is slightly dissociated, although the degree of dissociation may be excessively small. It will be clear that, if the partial pressure of the oxygen is ever so slightly greater than the dissociation pressure of any oxide of iron at the same temperature, oxidation will take place. Now Walden‡ has shown that at temperatures as

\* Advocated by the present author, see *Proceedings of the Chemical Society*, 1909, vol. xxv. p. 90.

† *Philosophical Magazine*, 1909, vol. xvii. p. 715.

‡ *Journal of the American Chemical Society*, 1908, vol. xxx. p. 1350.

high as  $1350^{\circ}$  C. the dissociation pressure of ferrosiferrous oxide,  $\text{Fe}_3\text{O}_4$ , is so small as to elude detection. At lower temperatures it will be presumably smaller still, and may well be of the same order as that of steam at  $350^{\circ}$  C. The dissociation pressure of ferrous oxide,  $\text{FeO}$ , is likewise excessively small. So that, whichever oxide is formed, there is nothing in these data to render the theory advocated by the present author untenable, and since it possesses several advantages over the usually accepted theory, the author regards it as being more probably nearer the truth.\*

If this be granted, we have here a means of calculating the dissociation pressure of the oxide of iron produced by the action of steam on the metal at  $350^{\circ}$  C., for it will be of the same order as the partial pressure of the oxygen in the steam.

From thermodynamical considerations, Nernst and Wartenberg† have arrived at the following equation connecting the dissociation of steam with its absolute temperature—

$$\log \frac{2x^3}{\left(2 + \frac{x}{100}\right)\left(1 - \frac{x}{100}\right)^3} = K - \frac{25030}{T} + 2.4 \log \frac{T}{1000} - 0.00016(T - 1000),$$

where  $x$  represents the percentage dissociation of steam, by volume, and  $T$  the absolute temperature. To the constant  $K$  the value 11.38 is assigned. By neglecting  $x$ , as compared with 100, and dividing throughout by 3, we arrive at the simplified equation—

$$\log x = 3.79 - \frac{8343}{T} + 0.8 \log \frac{T}{1000} - 0.00005(T - 1000).$$

At  $350^{\circ}$  C., therefore,  $x = 1.02 \times 10^{-10}$ , and the dissociation pressure of the oxide of iron is thus of the order of  $1.02 \times 10^{-12}$  atmospheres, which is, of course, far too minute to admit of direct measurement.

\* It is interesting to note in this connection that F. Glaser (*Zeitschrift anorgan. Chemie*, 1903, vol. xxxvi, p. 1) finds that  $\text{Fe}_3\text{O}_4$  is reduced by hydrogen gas at  $306^{\circ}$  C., and  $\text{FeO}$  at  $370^{\circ}$  C.

† *Zeitschrift für physikalische Chemie*, 1906, vol. lvi, p. 534.

## CONCLUSIONS.

The results obtained in this research may be briefly summarised as follows;—

1. Pure iron combines with ordinary air and with air dried over phosphorus pentoxide with increasing readiness as the temperature rises. Below  $150^{\circ}$  C. the oxidation proceeds too slowly to be readily detected.
2. When pure iron is heated in pure steam at temperatures ranging from  $350^{\circ}$  C. upwards, the metal becomes tarnished.
3. The author concludes that the action of steam on iron takes place in two stages, comprising, first, the dissociation of the steam; and, second, the combination of the dissociated oxygen with the iron, and the consequent liberation of free hydrogen gas.
4. If conclusion 3 is correct, the dissociation pressure of the oxide of iron produced at  $350^{\circ}$  C. cannot exceed  $1.02 \times 10^{-12}$  atmospheres.

In conclusion, the author has pleasure in acknowledging his indebtedness to the Research Fund Committee of the Chemical Society for a grant which has defrayed the greater part of the expense entailed by this work.

## THE SERVICEABLE LIFE AND COST OF RENEWALS OF PERMANENT WAY OF BRITISH RAILWAYS.

By R. PRICE-WILLIAMS (LONDON).

ACCORDING to the Board of Trade Railway Returns (1907) there are, roundly speaking, a little over 23,000 miles of railway open for traffic in the United Kingdom, of which about 13,500 miles consist of double and more lines, and about 10,250 miles of single lines, besides which there are 14,000 miles of sidings. The total annual cost of the maintenance and renewal of the permanent way and works amounted, roundly, to eleven millions sterling, nearly 15 per cent. of the entire working expenses, which have now and for some years past reached the exceptionally high figure of nearly two-thirds (63 per cent.) of the entire railway gross receipts.

In this paper the cost of the maintenance and renewals of the permanent way of fifteen of the principal British railways, having an aggregate of 15,118 miles of railway (equivalent to about 80 per cent. of the total mileage of the railways in Great Britain), will alone be dealt with, particulars of which expenditure have been furnished during the last ten years in some valuable tables in the C Appendix to the Board of Trade Returns. From these have been obtained the data from which the results in Table IV. (p. 193) have been compiled, giving in the case of each of these fifteen railways the expenditure in each year in wages and material, in the renewals of the permanent way, and also the average annual cost of renewal in terms per mile of railway considered—as a railway must necessarily be, whether a double or single line—as a thoroughfare for the conveyance of railway traffic. From a reference to the table in question, it will be seen that the average cost of renewals per mile varies from an average maximum of £418·18 per mile during the ten years, in the case of the London, Brighton, and South Coast Railway, to a minimum of £190·89 per mile in the case of the North

British; while the tonnage of goods and minerals per mile in the latter case is just double that of the London, Brighton, and South Coast. In another case, that of the Lancashire and Yorkshire Railway, with a maximum tonnage of 41,678 tons per mile of goods and mineral traffic, the average annual cost of renewals is only £291·07 per mile, very little above the average. Again, in the case of the London and North-Western, with the large tonnage of goods and minerals of 26,493 tons per mile, the average cost of renewals is as much as £325·83 per mile, as compared with the North-Eastern Company's average of only £236·26 per mile, with its heavy tonnage of 36,004 tons per mile of goods and minerals. Next comes the London and South-Western, with its average cost of renewals much above the average—namely, £319·47 per mile, with the smallest average of 6735 tons per mile. It is clear, therefore, that we must look for something more than the mere weight of tonnage to account for the exceptionally large cost of renewals of the permanent way of some of the principal British railways, and there is everything to indicate that it is mainly due to the greatly increased weight and speed of the passenger traffic which has occurred since the introduction of the better and much more durable material of steel rails, and partly to the increased weight and speed of the goods and mineral traffic. In this connection it will be as well to advert to the cost of the maintenance and renewal of the permanent way at the period almost immediately preceding the first introduction of Bessemer steel rails in the early 'sixties, particulars of which were furnished to the author by the chief executive of nine of the principal British railway companies at the time of the reading of his paper on the "Maintenance and Renewal of Permanent Way" at the Institution of Civil Engineers in 1866, a copy of which statement is given in the accompanying table. Side by side with this is given, for the purpose of comparison, the average annual expenditure and cost per mile of the renewals during the first ten years from 1865 to 1875 after the adoption, or partial adoption, of steel rails, and also of the present cost of the renewal expenditure of these nine railways as obtained from the returns of the fifteen British railways alluded to.

TABLE I.—*Maintenance and Renewals of Permanent Way of Nine Principal British Railways.*

Railway.	1847 to 1865.			1865 to 1875.	1897 to 1906.		
	Average Miles Open.	Amount of Renewals.	Average Cost per Mile per Annum.	Average Cost per Mile.	Average Miles Open.	Cost in Ten Years.	Average Cost per Mile.
	At Periods of Five and Three Years.						
L. & N.W. . .	755·6	1,906,859	370	307·53	1933·4	6,495,262	325·83
N. Eastern . .	662·0	867,576	206	232·01	1658·9	3,918,235	236·26
Midland . . .	546·6	775,750	225	311·26	1455·3	5,165,796	354·96
L. & S.W. . .	315·6	288,661	257	254·41	921·5	2,943,896	319·47
Gt. Northern . .	276·6	392,992	310	299·88	828·8	2,203,875	265·91
Lanc. & Yorkshire	255·4	768,924	377	397·07	565·2	1,645,094	291·06
S. Eastern & Chatham . . .	248·8	430,099	263	257·06	618·4	2,131,896	344·74
L., B. & S. C. .	180·6	219,514	266	239·33	448·6	1,875,982	418·18
M. S. & L. & Gt. Central . . .	160·2	85,760	200	271·29	*500·7	1,721,845	343·89
Totals and Averages . . .	3401·4	5,796,135	279	285·53	8930·8	28,101,881	320·60

The total cost of the renewal of these nine principal railways with iron rails during the eighteen and a half years prior to 1865, with an average aggregate of 3401 miles of way, during that period only amounted to £5,796,135, and to an average of £279 per mile of way. It rapidly increased during the first ten years, after the first partial introduction of steel rails, to £285·53 per mile, partly owing, no doubt, to the high price then of steel rails. Notwithstanding the great subsequent reduction in the price of steel rails to a lower figure than even the best iron rails, the expenditure in the renewal of way on these nine principal railways has, however, now reached an amount of £28,101,881, and £320·60 per mile of railway, during the short space of the last ten years—a fivefold increase in amount and now double the cost per mile in renewals—the mileage of these nine railways having increased from 3401 to 8930.

\* M. S. &amp; L., now Great Central.



The development of railway traffic since the introduction of steel rails has been enormous, as the few following figures testify:—

TABLE II.— *Railways in United Kingdom.*

Years.	Miles Open.	Gross Receipts.	Working Expenses.	Net Receipts.	Passengers.	Goods and Minerals.	Carriages and Waggons.
		£	£	£	No.	Tons.	No.
1907	23,108	121,548,923	76,609,194	44,939,729	1,239,481,315	515,887,116	810,416
1860	10,433	27,766,622	13,187,368	14,579,259	163,435,678	89,857,719	195,650
Increase	12,675	93,782,301	63,421,826	30,260,470	1,096,015,637	425,029,397	614,766

While the mileage during the last forty-seven years has only a little more than doubled, the working expenses have increased nearly sixfold, the number of passengers carried has increased nearly sevenfold, the tonnage of goods and minerals carried has increased nearly fivefold, while the number of carriages and waggons has only increased threefold; no doubt a considerable portion of the increase of the permanent way expenses is mainly due, as already stated, to the very large increase in the weight and speed of the passenger traffic, and partly to the very large increase in the tonnage of goods and mineral traffic, and also in some degree to its somewhat increased speed.

That the much greater strength and durability of the high class of steel material, of which Bessemer steel is the type, has largely contributed to the exceptionally rapid growth, not only of railway traffic in this country, but of its trade and commerce generally, there can be no question. No more striking recognition of this could better be given than was recently so felicitously afforded by the King in the handsome tribute His Majesty paid to the late Sir Henry Bessemer, to whose discovery of the process which bears its inventor's name he so justly attributed the remarkable development of engineering industries during the last fifty years.

This exceptionally rapid increase of railway traffic during

the period in question, however, was never anticipated, even by the most sanguine believers in the new process, including the author himself, and the effect of it is, it must be admitted, somewhat to discredit the estimates then made of the capability of the steel rails enduring the destructive effects of the wear and tear of the traffic for the long periods of time anticipated. This in no way detracts from the high character of the steel material, which has at least maintained all its fine qualities, and great improvements have since been made in the process of the manufacture, and large reductions in the price of the material.

As the records of the Institute proceedings testify, an intimate knowledge of the constituents of the material has been obtained by chemical analysis; but what in the case of steel rails are conspicuous by their absence in all these analyses are particulars of the physical qualities of the steel, and the amount of the tonnage and of the speed of the trains to which the rails have been subject, together with an exact measure of the wear of the rail-head during a given period. Full information on these points, together with Mr. Riley's chemical analyses and the late Mr. Kirkaldy's physical tests, are given in the author's paper, read at the Institution of Civil Engineers in 1866. Several methods have been adopted for ascertaining the amount of wear of the rail-head at an early period, notably that of the late James Price, M.Inst.C.E., by means of a sort of 40-foot turn-table, the rails of which were subjected to the wear of wheels loaded with given weights rotating at definite speeds round the 40-foot table, which gave approximately the amount of abrasion of the rail-head and check of the rail on a circular curve. Recently two other very ingenious methods were described in papers read at the Institute—one by Dr. Stanton, and the other by Mr. Saniter; but in none of these cases is any account taken of some of the most destructive effects which rails are subject to in practice, such as that of impact, the oscillations and concussions of the train, particularly on curves, the shearing away of the rail-head metal in flakes, and other effects. The late Professor De Morgan, of London University, stated to the author that in the case of a train travelling at a great speed

on a curved line, the oscillations and concussions partook of the character of a projectile fired from a curved cannon, and must be of a most destructive character.

In view of these facts, the author considers that nothing short of the actual experience derived from a careful register of the number, character, weight, and speed of the trains on those portions of a railway most severely worked will suffice to afford the requisite information.

The manufacturers of steel rails, to their great credit, have done all in their power to improve the quality and to increase the durability of the material; it behoves the railway engineer to see that this part of the business is carefully seen to. The result will, in the author's opinion, lead to large economies. No one, however, with any experience of railway working but must admit that the principal railways in this country are maintained in a thoroughly standard condition of efficiency for working the constantly increasing traffic, as is testified by the large annual amount per mile expended on maintenance and renewals.

As already stated, the working expenses of railways in the United Kingdom have now reached the exceptionally high average of nearly two-thirds of the gross receipts, whereas in 1860, the date immediately preceding the introduction of the Bessemer steel rail, the working expenses only amounted to 47 per cent. of the gross receipts, and during the previous twenty years which the author can recall, they had scarcely ever exceeded what in nearly all other great and well-administered commercial undertakings is regarded as the requisite normal expenditure of 50 per cent. It is not the purpose, however, of this paper to deal with this aspect of the question, but it is as well to bear in mind that nearly two-thirds of the total working expenses of these British railways have exclusive relation to the great iron and steel industries which supply most of the material required not only for the permanent way, but for the locomotive stock and large portions of the material of the carriage and waggon stock, as will be seen from reference to Table III., all of which are purely engineering matters affecting the cost of conveyance of traffic apart from the question of the administration of a railway.

TABLE III.—*Ten Years' Working Expenditure of Fifteen Principal British Railway Companies (1897 to 1906).*

Class of Expenditure.	Wages.	Material.	Totals.	Per Cent.	Average Annually.
Conveyance					
Maintenance and renewals—	£	£	£		£
Permanent way . . .	24,593,169	19,122,077	43,715,246	12·30	4,371,524
Locomotive stock . . .	21,098,706	19,985,914	41,084,620	11·56	4,108,462
Carriages and waggons .	17,524,413	26,519,282	44,043,695	12·38	4,404,370
	63,216,288	65,627,273	128,843,561	36·24	12,884,356
Locomotive running and coal . . . . .	50,954,022	47,511,494	98,465,516	27·68	9,846,551
	114,271,300	113,138,767	227,309,077	63·92	22,730,907
Traffic expenses . . .	128,322,469	...	128,322,469	36·08	12,832,247
	242,593,769	113,138,767	355,631,546	100·00	35,563,154

## PERMANENT WAY.

The permanent way of a railway in its widest sense, as the word itself most fittingly betokens, recognises no period of finality for its existence, so long as it continues to be the best available means for the conveyance of passengers, goods, and mineral traffic. It serves as a thoroughfare between different places and centres of traffic, and is equipped with mechanical appliances requisite for the transport of such traffic. The permanent way in this sense does not comprise merely the steel rails, sleepers, cast-iron chairs, points, crossings, and ballast, involving only an annual charge for their maintenance and renewal; but all that is essential to ensure safety and security in the conveyance of passenger and other traffic, the renewal of which, although indisputably constituting the main source of the permanent way working expenses, includes also the renewals or partial renewals rendered necessary by the natural decay of the "works of line," and other structures at much more distant periods, and the variations in periods for complete renewal, inclusive of the variations in the serviceable life of steel rails on different portions of the permanent way, render it impossible to determine the serviceable life of the permanent way except in its entirety and considered as a whole. Considered, however, in that sense, the average annual expendi-

ture in maintenance and renewals of the permanent way, in terms per mile of railway, whether it consists of double or single lines, during a sufficiently long period of years, is in reality the real equivalent of the annual death-rate of all classes of the perishable materials which constitute the per-

**TEN YEARS PERMANENT WAY RENEWALS  
OF 15 PRINCIPAL BRITISH RAILWAYS.**

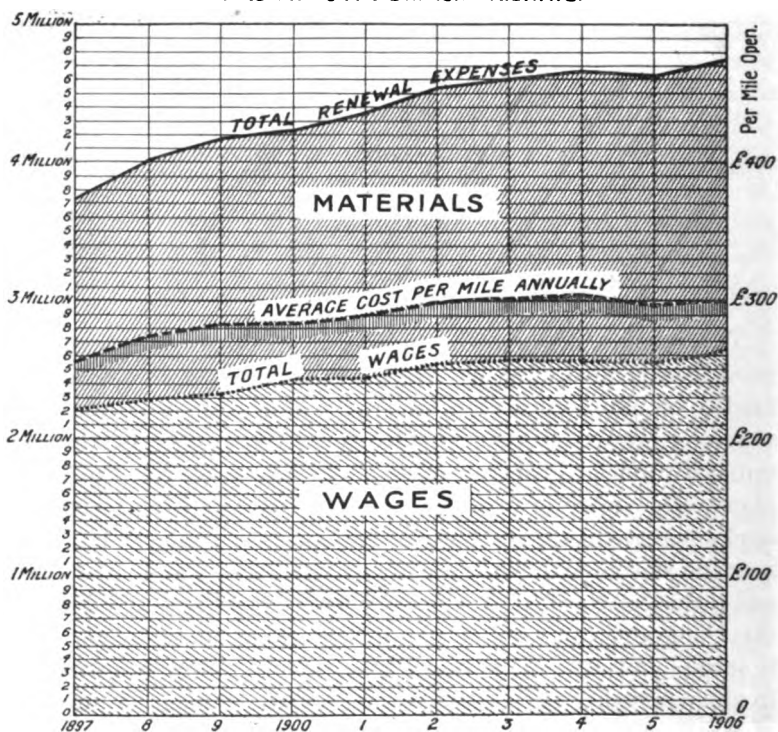


FIG. 1.

manent way of any railway. By way of illustration a period of thirty years may be fixed as a sufficient interval of time to obtain average and reliable results of the destructive effects of the wear and tear of traffic, and of the natural decay and exceptional causes necessitating complete renewal of the materials of all kinds. As will be seen from reference to Table V. (p. 194), of the results obtained in the case of the fifteen principal British railways during the last ten years,

means are afforded of determining very approximately the equivalent number of miles of permanent way and works of all descriptions which have become worn out and have been required to be renewed so as to have enabled the permanent way of the particular railway to have been maintained in a thorough condition of efficiency for continuing the ceaseless and constantly increasing traffic of British railways. All, in fact, that is required, with the data now available of the actual annual expenditure per mile of railway of these fifteen railways

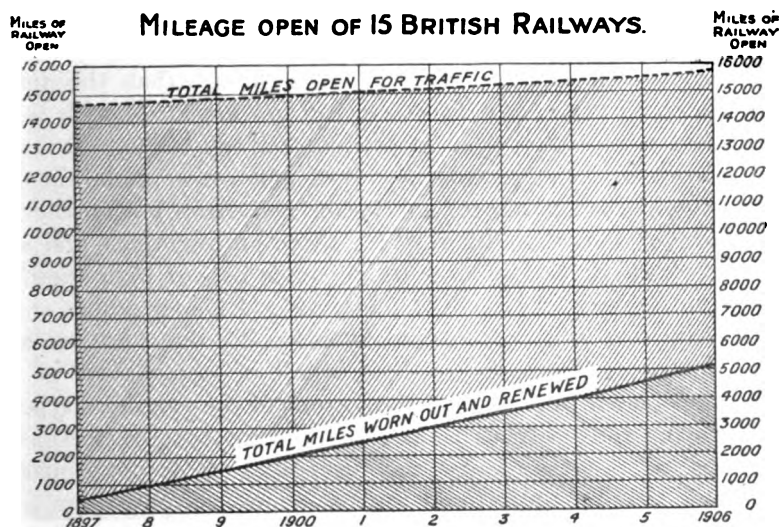


FIG. 2.

during the past long period of years in question, taking thirty years as a definite and reasonable maximum limit of serviceable life of all classes of materials, subject to the destructive effects of wear and tear and of decay, is to multiply each year's annual cost of renewals per mile of railway by the past thirty years' fixed period, and to divide the total amount of renewals expenditure during the last ten years by it, and we get the equivalent number of miles of railway—whether double lines or more, or partly double and single, or exclusively single lines, of each of the fifteen railways. In the aggregate

this amounts in the ten years to 5039 miles of railway, or, roundly, 504 miles annually, which have become worn out and have been replaced in most, if not all, cases with stronger and better materials, and as the traffic on these railways is still rapidly increasing, it may be satisfactory to the steel-rail manufacturers in this country to know that at least that quantity of worn-out steel rails will have to be simultaneously renewed during a similar period in the future. The permanent way of a railway—in fact, in its entirety, as has already been stated—has perpetual life, and it follows that every portion of it must necessarily share it also.

The late Sir John Hawkshaw, during the discussion on the author's paper in 1866 referred to, admitted that the improvements in the permanent way had not kept pace with the requirements of the rapid growth of railway traffic. It has since certainly been greatly improved and better maintained, and renewed with stronger and better materials, but on those portions of the main lines where there are junctions, and at all intermediate stations over which trains pass at high speeds without stopping, there are the knife-edged facing points and the main line rail crossings, more especially those known as the obtuse or diamond crossings, at all of which there is a gap in the main line rail, and they are all of the primitive types of crossing and switches as at the time Sir John Hawkshaw alluded to the permanent way in 1866. It is notoriously the fact that at these main line junctions and crossings, as the published records testify, some of the most terrible railway accidents have occurred. The recent very calamitous accidents at Salisbury and Shrewsbury junctions have since directed attention to the great defects and risks at junctions when trains are travelling at the high speed now attained, and to the need in such places for curves of greater radius, but that involves the adoption of longer and much more attenuated knife-edges, facing points or switch tongues, sharper-angled crossings, and bigger gaps in the main lines. A method has been devised for dispensing with the gaps in the main lines and of rolling much stronger and larger and tapered facing points which have been highly approved of by eminent engineers, amongst others, notably by the late Sir

TABLE IV.

Railway.	Average Miles of Rail-way Open.	Wages.	Materials.	Total Expenses.	Average Cost per Mile Open.	Equivalent Mile Worn Out.
	No. Dec.	£	£	£	£	£
Caledonian . . . . .	990.3	1,547,548	1,050,987	2,598,535	264.40	330.10
Great Central . . . . .	500.7	847,972	873,873	1,721,845	343.89	166.91
Great Eastern . . . . .	1116.1	1,908,770	1,470,507	3,379,277	302.78	372.03
Great Northern . . . . .	828.8	1,424,080	779,785	2,203,875	266.91	276.25
Great Western . . . . .	2679.6	3,248,732	3,600,453	6,849,185	255.61	893.20
Lancashire and Yorkshire . . . . .	565.0	997,461	647,633	1,645,094	291.07	188.32
London and North-Western . . . . .	1983.4	3,710,625	2,784,637	6,495,262	325.83	644.48
London and South-Western . . . . .	921.5	1,498,624	1,446,272	2,943,896	319.47	307.17
London, Brighton, and South Coast . . . . .	448.6	875,240	1,000,742	1,875,982	418.18	149.51
Midland . . . . .	1455.3	3,069,274	2,096,522	5,165,796	354.96	485.16
North British . . . . .	1278.5	1,632,015	908,570	2,440,585	190.89	426.16
North-Eastern . . . . .	1688.9	2,875,566	1,542,679	3,918,235	236.26	552.96
*South-Eastern, Chatham and Dover . . . . .	618.4	1,260,209	871,687	2,131,896	344.74	206.14
Taff Vale . . . . .	123.1	197,063	148,760	345,813	280.91	40.00
	15118.2	24,593,169	19,122,077	43,715,246	239.16	5038.39
		19,122,077		43,715,246	=	5039.3
		43,715,246		289.16 × 30		

\* During the earlier period of the ten years these two railways were separate companies.



Benjamin Baker and Sir Alexander Rendel, and especially by the late Sir Henry Bessemer, and the only objection made is the greater expense, and that the present types can be more cheaply constructed. With railway expenses at nearly two-thirds of the gross railway revenue, economy is most desirable, but where risk of accident and danger to life can be avoided, saving of expense, as Sir John Hawkshaw said on the occasion referred to, is false economy, to say the very least of it.

In conclusion, the author trusts that the fact that it is the business of members of this body by far preponderantly the greater portion of the material required for the renewal of the permanent way and of locomotive and waggon stock, the expenditure of which has amounted in the short period of ten years to nearly £129,000,000, may be considered some justification for drawing attention to the subject of the permanent way of British railways.

## SUMMARY.

FIFTEEN PRINCIPAL BRITISH RAILWAYS. TEN YEARS' MAINTENANCE AND RENEWALS OF PERMANENT WAY (1897 TO 1906).

TABLE V.—*The Ten successive Years.*

Years.	Miles Railway.	Wages.	Materials.	Total.	Per Mile.	Expen- diture in Past 30 Years.	Miles worn out.
		£	£	£	£	£	No.
1897 .	14,605	2,199,558	1,519,225	3,718,783	255·31	7659·30	486·81
1898 .	14,773	2,261,725	1,774,353	4,036,078	275·14	8254·20	492·43
1899 .	14,811	2,333,775	1,843,111	4,176,886	282·01	8460·30	493·70
1900 .	14,900	2,425,384	1,794,345	4,219,729	283·46	8503·80	498·67
1901 .	15,043	2,434,552	1,934,507	4,369,059	290·50	8715·00	501·43
1902 .	15,095	2,532,418	1,983,618	4,516,036	299·17	8975·10	503·17
1903 .	15,262	2,587,784	2,021,299	4,609,083	301·96	9058·80	508·80
1904 .	15,350	2,586,205	2,085,832	4,672,037	304·36	9130·80	511·67
1905 .	15,536	2,586,909	2,063,201	4,650,110	299·47	8984·10	517·86
1906 .	15,899	2,644,859	2,102,586	4,747,445	301·30	9009·00	526·97
Totals and Averages.	151,184 15,118	24,593,169 ...	19,122,077 ...	43,715,246 ...	... 289·43	... 8684·10	5039·31 ...

*DISCUSSION.*

Mr. EBENEZER PARKES, M.P. (West Bromwich), said he wished to ask whether rates and taxes were included in the total working cost of the railways.

The PRESIDENT: I think I may state without hesitation that they are included in the total value of 63 per cent.

Mr. EBENEZER PARKES said he would like to ask what proportion the 63 per cent. of the total cost of railways at the present time bore in rates and taxes to the 47 per cent., the total cost of the management of railways in the year 1860.

The PRESIDENT said he was afraid he could not allow the discussion to diverge in that direction. It would never be concluded if that occurred.

Mr. EBENEZER PARKES said that, from his own point of view, it was not a controversial matter. All he wanted to know was how much the increase in rates and taxes compared as to the 47 per cent. and 63 per cent. cost quoted in the paper.

The PRESIDENT said he was, after all, glad that Mr. Parkes had raised the point. It was quite obvious that, if a discussion of that kind were permitted to diverge from Mr. Price-Williams' paper, points of a very far-reaching character would be raised which it would not be possible to discuss there. He proposed to offer some observations shortly on the subject of the paper, but he thought he would have to ask gentlemen to confine themselves to the point raised by Mr. Price-Williams, namely, the amount which was now required for the steel renewals on railways, and what proportion it might bear to other expenses in connection with railways. Any discussion differentiating as between the remnant left after deducting steel expenditure he felt compelled to rule out of order. He thought that Mr. Parkes would see the reasonableness of that ruling, and he (the President) was glad that such a distinguished person as Mr. Parkes should have permitted the rule against him.

Mr. T. HURRY RICHES (Cardiff) said that, as one concerned with rolling stock, he was perhaps not much of an authority on steel rails, but there were at least some points in reference to the wear of steel rails which materially interested those connected with rolling stock. He did not notice that Mr. Price-Williams, in his paper, had made much allusion to the influence of the changed class of steel used in tires of to-day compared with that of many years ago. Neither had Mr. Price-Williams commented upon the sectional profile of the tires used to-day as compared with those used in days gone by. He (Mr. Hurry Riches) knew that

a great deal of influence had been exerted by the form of the tire flange and the cross-section of the tire upon the life of the rail. He thought that it was a very good thing that recently, in fact really only within the last few years, closer attention had been given, and more co-ordination had taken place between the engineers of the road and the engineers of the rolling stock with a view to making the sections of the rails and the sections of the tires work in better harmony one with the other. He thought it was not only a question of the material which formed the rail, but also one of the section and class of material that ran upon it. There was another point to which he would call attention, and that was the material increase in the tare weight of the vehicle. Mr. Price-Williams had very justly called attention to the fact that the number of vehicles used in proportion to the tonnage carried was now much fewer than it was in years gone by, and that very fact indicated that the increase in capacity of the vehicles had been considerable; indeed, not only had there been an increased capacity in that way, but the tare weight had more than proportionately increased. Therefore it was not only the paying load which might fairly be included in the wearing weight on the rails, but also the non-paying load, the tare weight, which materially helped to increase the gross tonnage carried over the rails. He could not help thinking that the paper which Mr. Price-Williams had been good enough to bring before them was one which would give them a very great deal to think about. The wear and tear of permanent way and rolling stock was one of vital importance to the railways to-day, and as time went on, and working expenses necessarily, although unfortunately, increased, there would arise very serious questions of cost which would be reflected ultimately on the capacity to earn dividends. He hoped that the question which Mr. Price-Williams had so clearly brought before them that day would produce further deep thought with a view of improving, if possible, the sections of the rails and tires, and further, if possible, of improving the wearing capacity of the rails themselves.

The PRESIDENT said he felt his position to be somewhat awkward in having to continue the discussion, because he had hoped that some person with more experience in rail making would have been willing to address the Institute on the subject generally. The importance of the question which Mr. Price-Williams had brought forward could not be underestimated. In Great Britain the prospects of any large increase in rail mileage did not seem to be very great. It was a very small country with 23,000 miles of railway, and had probably about reached its fullest development. To those who were manufacturers of rails, the wear and tear of rails in Great Britain became, therefore, a matter of very great interest. Of course, when a view was taken of the world at large—and, after all, of all the trades of the United Kingdom the steel trade was quite the most international trade of any—the question assumed a somewhat different aspect because the wear of rails on the railways of the world would be perfectly stupendous in extent, and it would be interesting to consider, and he hoped that some statistician would, in the near future, consider what it required year by year to maintain the railways of

the world in a condition to carry on their business, and to meet its growing requirements. He was leaving out of account for the moment the obviously immense demand for rails which still existed, and would necessarily continue to exist for a very long time to come, in the further development of railways. Therefore, though the question which Mr. Price-Williams brought before the Institute was of extreme interest from two points of view, it really fell into insignificance in comparison with the third point. The two points of view were the demand for the renewals of rails at home, and that for the renewals of rails for the world at large; while a third point of view was that of the demands of the world for new railways. Unfortunately for a number of reasons—the enumeration of which would lead to bitterly controversial ground—Great Britain possessed, as was illustrated by Mr. Price-Williams, the most ineffective statistics in connection with railway management that it was possible to conceive. He (the President) only had to draw attention to one single point to illustrate that. Mr. Price-Williams gave all that he could give in advancing the tonnage of goods and minerals, but he was obliged to leave out of account—because he had not got them—the tonnage of passengers. That was a very important item, as he thought he would be able to show. And, in fact, when the matter came to be considered, the real point of interest from the standpoint which he was taking up was not the quantity of tons of goods or of minerals, but the quantities of tons of trains rolling on axles—the dead weight of the trains. A passenger train had far more dead weight per ton of persons carried, far more dead weight per pound of revenue earned, than a mineral train. Upon that point, however, he wished to reserve himself, for he had no figures to guide him. It was possible, however, to see how that consideration affected the figures which Mr. Price-Williams had laid before the Institute that day. While the former was speaking, he (the President) prepared one or two statistics to “administer”—there was nothing so unpalatable as statistics, and therefore he used that phrase—to administer to his unfortunate hearers. In 1860—he accepted Mr. Price-Williams’ figures, which were no doubt correct—the tonnage of goods and minerals carried was given as being 89,000,000. In 1907 it was given as 515,000,000, no doubt a very important increase. Taking that number per head of the population, what did it amount to? He asked the question because that was the point they had to consider for the moment. There were 13 tons carried per inhabitant at the present time, against  $4\frac{1}{2}$  tons carried per inhabitant in 1860. So that the quantity of goods and minerals had increased threefold— $4\frac{1}{2}$  as against 13. On the other hand, what had happened in the matter of population? The number of persons carried per head of population in 1860 was 8, whereas in 1907 it was 31, or nearly fourfold. But let them further consider what a railway train carrying passengers was in 1860, and what a railway train carrying passengers was in 1909. If any of those present got into a train which was going to run a hundred miles and did not find a restaurant car, they would be fit to tear the unfortunate directors to pieces because they had not provided the means of luncheon. Apparently it was not very far distant when, believing that it was not at all difficult to get

something out of nothing, the railways would be called upon not only to carry all the distinguished persons present who had taken first-class tickets in a sleeper from one point to another at an extremely low rate, but, in all probability—he was speaking as a railway director—they would be compelled to find third-class sleepers. In point of fact, the cost per seat over the period in question had been multiplied, he hardly liked to say how many fold. So that not only were the railways carrying four times as many passengers as they carried at the earlier date, but they were carrying them in trains which weighed, he would venture to say, very nearly four times as much per passenger. Any statistics which lost sight of those very important facts were really (with all deference to Mr. Price-Williams, and interesting as were the figures which he laid before them) absolutely valueless; and until there was some method of gauging the real user, due to the use made of the line itself, it was perfectly hopeless to draw any conclusions on the matter. He did not undervalue the paper at all, and he hoped that Mr. Price-Williams would clearly understand that he realised the vital importance of the subject. But it showed how difficult it was to survey it in a way in which it could be made of use to those engaged either in the management of railways, or in providing material to enable the directors to manage the railways to any good purpose.

To turn to another subject, a subject dealt with by Mr. Price-Williams, and of very great importance indeed, what had been happening in that respect? The public and the railway engineers had put the tire-makers under more and more severe obligations in the matter of tires. Their form, their construction, and the way in which they behaved when running, were all the subject of continual criticism, not only by the railway engineers, who approached the question with the earnest desire to get the best article they could for the money, but also by the public. Accordingly, the tire manufacturer had been put under the most severe obligations. The rail-maker had equally been compelled to comply with all sorts of analyses and tests, putting him under most onerous terms. Often the conditions which were prescribed for him were contradictory in terms; as, for example, that the rail should be of a certain hardness and at the same time possess a certain resistance. There was a difficult balance between two very largely contradictory qualities. But so far as he knew there had been no endeavour to see in what way the relation between the rail and tire should be adjusted so as to reduce the wear of each to a minimum. There could be no question that that was a most important subject. There could equally be no question that it was obviously the duty of all parties to make that most important part of rolling stock, the tire, as trustworthy as it was possible to make it. The breaking of a tire, or the failure of a tire, next to the failure of an axle, was the most untoward event which could happen in railway practice. Therefore every endeavour should be made to assure the durability of the tire. But had there been any endeavour to balance as between the tire and the rail? He would ask them to bear in mind that the conditions under which railway management was conducted to-day had altered to a very remarkable extent in so far as not only had the speed of running been very

greatly increased, but also, what was equally important, the average speed over the line had increased. In order to accomplish that it had been necessary to draw up trains with very much greater rapidity than was customary in bygone years. Those who were old enough to remember would recollect that a train used to slow down about two miles before it got into the station, but now if it began to slow down about a quarter of a mile outside the station that was about all that could be allowed in order to reach its destination within the scheduled time.

He would like permission to advert again for a moment to the question of the relation between passenger and other traffic. Of course, he spoke now rather for the great mineral-carrying lines than for those lines which were specially passenger-carrying lines. But a great many of those which were largely passenger-carrying lines were included in the tables given by Mr. Price-Williams. In the case of the North-Eastern, the revenue was divided in approximately equal thirds between (1) goods, (2) minerals, and (3) passengers and parcels. Mr. Price-Williams would therefore see how important it was, so far as the great mineral-carrying lines—such as the lines, speaking generally, in the northern part of England—were concerned. How much more important must it be in those lines in the south of England where mineral traffic became a less important matter? It emphasized the necessity of obtaining some better means of judging how far the wear and tear of the railway was to be distributed between those two divisions, goods and minerals on the one hand, and passengers on the other. The general importance of the question, as he had said before, could not be undervalued. If the railway business of the country was to be carried on, it was incumbent upon those who were charged with it—whether they were, as at present, private individuals, or whether they were civil servants of the State—to carry on the traffic as cheaply and as economically as possible. Thus the subject raised by Mr. Price-Williams became one of the greatest importance. He did not think it would be possible to choose a subject of more vital interest to the country at large than the question of economical railway management. So far as it concerned the Iron and Steel Institute, he would venture to affirm that there was no subject which could be discussed at its meetings with more profit than those which were raised by Mr. Price-Williams in his very interesting paper.

MR. H. A. WATSON said that he was sorry to say that he did not hear the whole of the paper read, nor the whole of the discussion which had taken place upon it. He gathered, however, from the remarks of Sir Hugh Bell, that the real point which Mr. Price-Williams wished to raise in his paper was the increasing expenditure on the permanent way of British railways in proportion to the amount of business that they were doing. There could be no doubt that that was a very important question indeed. In order to discuss that question, it seemed to him that the first thing that they ought to have clearly in their minds was the nature of the standard of comparison to be applied. He thought Sir Hugh Bell had put the difficulty very clearly, and perhaps, if he

might be allowed to say so, had also indicated the inadequacy of the standard that Mr. Price-Williams raised in his paper. The fact that British railways were having to do so much more for the payment which they received from the public, both in the conveyance of passengers and merchandise, made the comparison very much more difficult than it would have been if the conditions had remained the same as they were in the year 1860. The one or two factors alone to which Sir Hugh Bell called attention he thought altered the position in a radical way. If they took into account the fact, for instance, that the dead weight per ton of a passenger carriage in proportion to the number of people conveyed had risen to the extent which Sir Hugh Bell had stated, it made a very great difference in the amount of wear and tear of the roads in earning the same amount of money. In 1860 he might say that the average railway carriage would weigh 12 tons, and convey sixty people. Now corridor carriages—the ordinary corridor third-class carriage which the North-Eastern Railway ran on their east coast trains to Scotland—weighed over 30 tons and only conveyed forty-two people, so they would see there was bound to be a very much greater wear and tear of the rails in conveying the same number of people than there used to be in 1860. Therefore he did not think it was fair to say that, because the British railways were spending more money in the maintenance of permanent way in proportion to the number of passengers carried, therefore they were being worked less efficiently; at all events that was not putting the case quite fairly so far as the railways were concerned. The same criticisms applied to some extent with regard to merchandise traffic; but that particular point respecting increased weight of rolling stock was really more a question of the conveyance of passengers. Another instance he could give them was one also referred to by Sir Hugh Bell, and that was the enormous dead weight of sleeping carriages. They had sleeping carriages on most of the night trains to Scotland, and those coaches weighed 35 tons and only conveyed ten people. Therefore they had a dead weight of over 3 tons per passenger. If they compared that with the sixty people in the 12-ton carriages, they would see what a very much greater wear and tear of permanent way was involved in doing the same business. As a matter of fact there was less money also, nowadays, per passenger, because long-distance fares had tended to diminish as compared with those of 1860. Long-distance fares, such as those to Scotland, were cheaper now than they used to be at that time. There had not been the same dead weight increase in the matter of merchandise stock that there had been so far as the conveyance of passengers was concerned. Sir Hugh Bell reminded him that very many attempts had been made of late to provide higher capacity wagons, and that many of the railway companies had been able to reduce the ratio of dead weight to paying load in the matter of merchandise vehicles. The introduction of large wagons of 20 and 40 tons capacity had reduced the ratio to something under 50 per cent.; that was to say, that slightly over half the gross load behind the engine consisted of paying freight. Another way by which the conclusion that the conditions to-day were more onerous than they were in 1860 might be

arrived at, so far as wear and tear of permanent way was concerned, was by taking into account the much greater weight of the locomotives. Nowadays trains were run with much heavier loads, and that involved heavier locomotives, and there was more wear and tear of the permanent way, due, he supposed, to the inevitable amount of slipping that would take place between the wheels and the rails, however well each of the two were constructed by themselves, or however scientifically they were constructed in relation to one another.

Mr. L. N. LEDINGHAM (Sheffield) said one point just struck him respecting the comparative wearing of rails, and that was that when a company had their tires and rails adjusted in working order they worked smoothly together as far as possible, but when some other rolling stock belonging to another railway, and having tires not turned up exactly the same as their own tires was used, possibly they would have a slightly different effect on the rails when running.

Professor H. LOUIS (Newcastle) said he desired to ask one question with regard to a sentence in Mr. Price-Williams' paper that might have considerable bearing on the subject. On p. 192 Mr. Price-Williams drew attention to the accidents at Salisbury and Shrewsbury Junctions, and emphasised the need in such places for curves of greater radius. That was a point that had been long on his (Professor Louis') mind, and he was now asking specially for information with regard to it. When railways were first built in Great Britain the curves were laid simply as arcs of circles. For some time past investigations, especially on the Continent, had shown that the circular arc was not the best curve, and modern engineering practice went entirely on the lines of laying curves as so-called curves of adjustment or transition curves, such as cubic parabolas, for example. The harm that was done by the simple circular arc was, of course, obvious: when a train passed abruptly from the perfectly straight line to the circular curve there must necessarily be a shock, and that shock could only be got over by those modern methods of using curves of adjustment, with a radius gradually decreasing from infinity to the required radius of the curve. He knew that those old curves were being changed gradually on some railways, but doubted whether this practice was being extensively enough adopted. He would like to ask the following questions: Had many of the old-fashioned circular curves been modified of late years? Were such accidents as those at Salisbury and others due to the fact that they had not modified their curves in accordance with recent engineering practice? and could anything be said as to the difference between the wear of a rail laid on the old-fashioned circular arc and a rail laid on the more modern methods? It struck him that those were points of very great importance in that discussion, and he was asking for information which he hoped the author of the paper would be able to give him.

Mr. PRICE-WILLIAMS, in reply, said that with regard to the various points raised, and more particularly as to the question of the dead weight



and the great changes that had occurred, he could only entirely emphasise what the speakers had said as to the importance of the question. But in his paper he confined himself strictly to facts and figures. He said nothing with regard to the dead weight. Of course it was obvious that since 1860 the weight of engines had increased enormously, and the tare weight of the wagons as well. That all emphasised what he had said. He was simply pointing out that the live weight alone had not accounted for the enormous wear and tear. It showed that a great deal had been done in that way. But with regard to the passengers, as the President remarked, he had said nothing. He had no means of ascertaining directly what that weight was. With regard to the length and the weight of the passenger train, and the enormous disparity between the tare weight and the live weight, it had—perhaps much more than he had thought—contributed to the great amount of wear. He had merely directed attention to the subject from the facts that were before him. The President had alluded to statistics, and he (the speaker) could not help saying that he did not think that either in that or in kindred institutions had justice been done to the value of statistics. He considered, in dealing with this question, that with regard to the administration of railways to which the President had referred, they had really a great deal yet to learn, and that the Institute, representing the staple interests of this country, was most deeply interested in the reduction of the cost of conveyance. He would add nothing further on this subject beyond making one remark which, perhaps, might surprise members present to know that at the very time of which he was speaking, the railway companies admitted that they were unable to tell, from the authorised railway rates and charges, what it cost them to carry a single ton of goods, minerals, or passenger, or a single article. The general manager of one of their principal railways, when that subject was brought forward by himself in a paper he read at the Royal Statistical Society soon after the bill dealing with railway rates was passed, admitted and pledged his reputation as a railway manager that even if the additional information he (the speaker) asked for was supplied, it would be utterly impossible to tell what it cost to carry a passenger, or a ton of goods, or minerals. To his mind such a state of things was most discreditable, more especially to the engineering profession, inasmuch as 63 per cent. of the working expenses were purely railway engineering expenses. All he would impress upon the members was, that it was of vital importance to them that every effort should be made, having regard to foreign competition, to secure that the cost of conveyance of the valuable materials, the products of their respective industries, be reduced to the lowest possible figure. With regard to the remarks made by the last speaker as to curves, he should state that that subject had recently been brought forward at a kindred Institution, the Institution whose hospitality they were enjoying. It was a most vital subject, and the speaker was quite right in what he said as to the original curves being circular. The accidents which had been alluded to had shown the need of very great improvement in the laying out of curves. Robert

Stephenson told him, when his invention of a cyclograph \* which met with that great engineer's approval, was presented to, and accepted by, the Institution of Civil Engineers, that his ideal of the true curve for a railway was a parabola.\* Professor Whewell of Cambridge also made the same remark, and it was quite evident now that very great improvements in thus graduating the curves at junctions would have to be carried out, and in fact were now being made. There was no doubt that the most dangerous parts of railways now were the junction curves. He had hoped that the civil engineers, whose province that was, would soon make very great improvements in the character, more especially of junction curves. He had only to thank the members for the consideration they had given to his paper.

The PRESIDENT: I have to move that the best thanks of the Institute be given to Mr. Price-Williams for his valuable paper.

Carried by acclamation.

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### CORRESPONDENCE.

Mr. J. A. F. ASPINALL (Manchester) wrote pointing out that Mr. R. Price-Williams had taken the figures given by the Board of Trade which showed the miles of railway irrespective of the number of lines of way each company possesses. Some companies had but single lines, others double-track, others many miles of four-track, and again there were some cases of six-track, all irrespective of sidings. To divide the permanent-way expenses merely by the length of country covered gave an erroneous impression of the cost of maintenance per mile. The more correct way was to divide by the miles of single line possessed by each company.

Most of the railway companies published in their half-yearly reports a statement showing how many miles of single, double, four, and six tracks they owned, and those statements were also given by the Board of Trade in their Annual Returns (Statement No. 2, and Appendix "B"). If Mr. Price-Williams' Table IV. were modified by taking the miles of single track and dividing those figures into the total expenditure for wages and materials for the ten years 1897 to 1906, the cost per mile became a very different figure, and the conclusions drawn from the original Table IV. would need modification. Even in that case, the immense differences which existed between the proportion of mileage of sidings to mileage of running track owned by the several companies would make a great change in the figures, which would, so far as the expenditure was concerned, be very largely affected by the greater or lesser mileage of sidings. The effect could be roughly gauged by an examination of the Board of Trade Railway Returns which showed the total length of single track in the case of each company, including

\* In place of the cyclograph referred to, Mr. Price-Williams has designed a parabola-graph, which was exhibited at the meeting.

TABLE "A."—Statement showing the Proportion of Passenger and Goods Train Miles respectively in Relation to Miles of Track. (Year 1908.)

Railway.	Miles Open, Single Track.	Passenger Trains.		Goods Trains.		Total Number of Journeys per Mile of Single Track.	Percentage of User.	
		Train Miles.	Number of Journeys per Mile of Single Track.	Train Miles.	Number of Journeys per Mile of Single Track.		Passenger Trains.	Goods Trains.
London & North-Western	4,015	29,964,219	7,463	18,768,425	4,675	48,732,644	61	39
Midland . . . .	3,127	22,432,019	7,174	25,304,020	8,092	47,736,039	47	53
Great Western . . .	4,824	31,638,512	6,559	19,923,751	4,130	51,562,263	61	39
North-Eastern . . .	3,069	17,240,938	5,636	11,861,217	3,877	29,102,155	59	41
London & South-Western	1,733	15,557,790	8,977	4,400,448	2,589	19,958,238	78	22
Caledonian . . . .	1,712	8,919,418	5,210	6,278,354	3,667	15,197,772	59	41
Lancashire & Yorkshire .	1,318	13,133,015	9,964	5,219,963	3,961	18,352,978	72	28

TABLE "B" (Modification of Mr. Price-Williams' Table IV).—Statement showing the Average Expenses incurred in Maintaining the Permanent-way of the Railways named below. Ten Years, 1897 to 1906.

Railway.	Average Number of Miles open of Single Line of Running Track, exclusive of Sidings.	Average Cost per Mile of Single Track per Annum.		
		Wages.	Materials.	Total.
Caledonian . . . . .	1662·8	£ 1,547,549	£ 1,050,957	£ 2,598,506
Great Central . . . . .	979·0	847,972	873,873	1,721,845
Great Eastern . . . . .	1784·5	1,908,770	1,470,507	3,379,277
Great Northern . . . . .	1662·3	1,424,090	779,786	2,203,875
Great Western . . . . .	4152·9	3,248,732	3,600,453	6,849,185
Lancashire and Yorkshire . . . . .	1172·8	1,001,461	648,633	1,650,094
London and North-Western . . . . .	3665·0	3,710,625	2,784,637	6,495,262
London and South-Western . . . . .	1605·6	1,488,624	1,445,272	2,943,896
London, Brighton and South Coast . . . . .	811·1	875,240	1,000,742	1,876,982
Midland . . . . .	2742·8	3,069,274	2,096,522	5,165,796
North British . . . . .	1790·2	1,632,015	908,570	2,440,585
North Eastern . . . . .	2870·5	2,375,558	1,542,679	3,918,235
South Eastern and Coast . . . . .	1183·2	1,260,209	871,687	2,131,896
Taff Vale . . . . .	211·9	197,063	148,760	345,813
Totals and Averages . . . . .	26084·6	24,597,170	19,123,077	43,720,247
		94·26	73·28	167·54

"Average Miles Open" arrived at as follows :—  
 Single and double lines . . . . . 1897 to 1902  
 Single, double, three, and four lines or more . . . . . 1903 to 1906

sidings, and then deducing by means of Appendix "B" in the same returns (which gave the number of miles of track up to four or more) the number of miles of sidings there were as distinguished from running lines. If, following out the idea of division by miles of single track, a new table were constructed (which might be called "A") for seven of the chief railways for the year 1908, the mileage became slightly different from the average of the ten years previously spoken of, but it was possible to show in a somewhat interesting way the number of journeys per mile of single track for passenger and goods trains, and reduce those journeys to percentages of the whole, so as to show the comparative user by goods and passenger trains respectively. That gave a better idea of the real work done than if the tonnage of goods over the whole of the railways were taken irrespective of the number of miles that tonnage had been carried.

The difference of £5000 between the Lancashire and Yorkshire figures £1,650,094 in Table "A" and the lower figures £1,645,094 given by Mr. Price-Williams in his Table IV., was accounted for by the fact that the Board of Trade Returns for 1900 contained a mistake in regard to the amount paid by the Lancashire and Yorkshire Railway for wages and materials that year.

Mr. PRICE-WILLIAMS, in reply, thought that Mr. Aspinall had either not read the paper or had misunderstood its purport. The figures given in it were taken from Appendix "C" to the Board of Trade Returns, which showed separately the wages and materials, not only of the permanent way, but, as stated in the paper, the expenditure on works of line, stations, fences, gates, warehouses, &c., &c. These were essential factors in the question of the actuarial character to which no allusion was made by Mr. Aspinall. Every railway engineer was familiar with the process and use for certain purposes of converting the mileage of railway into terms of single line, but for the purpose of the paper there was no meaning in showing the number of journeys per mile of single track for passenger and goods trains.

It was stated by Mr. Aspinall that some railway companies had entirely single lines. That, however, was not true of any of the fifteen principal railways dealt with in the paper, the mileage of which constituted 80 per cent. of the railway mileage in the United Kingdom. Moreover, it should be remembered that on those which had double, treble, and quadruple lines the single line carried the traffic both ways, and, on some single lines, the traffic both ways was heavier than on each line of a double way.

With regard to the error noted by Mr. Aspinall in the Board of Trade Returns for the Lancashire and Yorkshire Railway for the year 1900, he (Mr. Price-Williams) had, as a rule, found those Returns singularly accurate, particularly in the case of the very valuable Returns given for the last ten years in the "C" Appendix. Mr. Aspinall's Table B, put forward as a modification of Table IV. in the paper, had no useful bearing upon the subject, and his Table A, containing estimates of the proportion of passenger and goods train miles, had nothing to do with the main

object of the paper. In adopting, as Mr. Price-Williams had done, the mileage of railway open as a standard and common measure of length of each railway for the purpose of comparison at different periods on the same railway, and also on different railways, he had, as explained in the paper, taken into full and correct account, in terms of railway mile in its entirety, the cost per mile of the maintenance and renewal of each mile of railway, to which was correctly attributed its due average proportion of the annual cost of single, double, and more lines wherever they occurred, and also of the sidings at terminal and intermediate stations. Strictly considered, the cost of the maintenance and renewals of terminal and intermediate station sidings should be charged as terminal traffic expenses, which were not dealt with.

## TESTS OF CAST IRON.

BY E. ADAMSON (SHEFFIELD).

THE very great variations in the tests which have been obtained from cast iron from time to time, and the differences of opinion which exists as to the best methods of testing, determined the author to make the comparative tests which form the subject-matter of this paper. These tests were all carried out in actual foundry practice, the metal used being taken chiefly from the ordinary cylinder mixtures, which remained over and above what was required for the tests used in the ordinary shop work. The object of the tests was in no way to secure the highest possible results, but, if possible, to arrive at the differences in results under varying working conditions.

The author wishes to state his appreciation of the work of T. Turner, W. R. Johnson, West, Keep, and Outerbridge, on cast iron. Their results are all of much value in the intricate problems involved in the study of that material.

## TENSILE TESTS.

Nine boxes were used for casting the twenty-four tensile test-bars and six transverse test-bars from the one ladle. The tensile bars numbered 1 to 3 were cast to a diameter of  $\frac{7}{8}$  inch, Nos. 4 to 6 to a diameter of  $\frac{3}{4}$  inch, Nos. 7 to 9 to a diameter of  $\frac{5}{8}$  inch, and Nos. 10 to 12 to a diameter of  $\frac{1}{2}$  inch. The tensile bars from 13 to 24 inclusive were cast 1 inch diameter, and were machined down to the same diameter as Nos. 1 to 12, and the six transverse test-bars were then cast on edge at an angle of  $22\frac{1}{2}^{\circ}$ . Table I. shows the results of the tests obtained, which appear to indicate that the bars which have been machined give better results than those which have been tested as cast with the skin on. The results of the transverse and deflection tests are given later.

TABLE I.—Tensile Tests. Varying Diameters as Cast and Turned.

Numbers.	Analysis.							Diameter of Test-bars.		Tensiles.	
	T. C.	G. C.	C. C.	Si.	S.	P.	Mn.	As Cast.	Turned.	Average of each Diameter.	Mean over all Areas.
Skin on as Cast.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Inch.	Inch.	Tons per Sq. In.	Tons per Sq. In.
1-3	...	3.36	2.98	0.58	1.53	0.11	1.19	0.80	$\frac{1}{2}$	...	12.32 ...†
4-6	...	"	"	"	"	"	"	"	$\frac{3}{4}$	...	12.76 ...†
7-9	...	"	"	"	"	"	"	"	$\frac{5}{8}$	...	12.11 ...†
10-12	...	"	"	"	"	"	"	"	$\frac{1}{2}$	...	13.69 12.72†
...	13-15	"	"	"	"	"	"	"	...	$\frac{3}{4}$	Flaws. ...†
...	16-18	"	"	"	"	"	"	"	...	$\frac{3}{4}$	13.20 ...†
...	19-21	"	"	"	"	"	"	"	...	$\frac{5}{8}$	14.72 ...†
...	22-24	"	"	"	"	"	"	"	...	$\frac{1}{2}$	13.96 13.96†
<i>Duplicating Tests 13 to 24.</i>											
...	40-42	3.54	2.96	0.58	1.30	0.077	0.59	0.68	...	$\frac{1}{2}$	13.69 ...†
...	43-45	"	"	"	"	"	"	"	...	$\frac{3}{4}$	15.62 ...†
...	46-48	"	"	"	"	"	"	"	...	$\frac{5}{8}$	15.59 ...†
...	49-51	"	"	"	"	"	"	"	...	$\frac{1}{2}$	15.38 15.07†

\* Flaws in all bars.

† From one ladle.



Twelve tensile test-bars and four transverse test-bars were cast from the same ladle, duplicating tests Nos. 13 to 24, in order to confirm if there were any special diameter of the turned bars which gave the highest results, but from the second part of Table I. it would appear that the bars turned down to  $\frac{3}{4}$  inch to  $\frac{1}{2}$  inch show very little variation in the test per square inch. Five sets of bars—three tensile and two transverse bars, each with the same percentage of silicon (the latter cast on edge at an angle of  $22\frac{1}{2}^{\circ}$ )—were cast from the same ladle of metal as those entered in Table I., but varying percentages of 50 per cent. ferro-silicon were added to each small ladle (taken from the larger ladle), in order to increase the percentages of silicon in the test-bars. This was duplicated.

Table II. shows the results of these tests, which were made with the idea of ascertaining the value of the use of high percentages of ferro-silicon in actual foundry practice. A number of the tensile tests showed flaws, and as the tests obtained therefrom were in consequence very low, they have not been included, as the true area of the bar could not be obtained. The sound bars were all tested, and the average results taken as the mean of each set of bars. In Table I. the percentages of silicon which were actually added to the metal are shown, together with the increasing percentages of silicon, and it is noticeable that in spite of the silicon being increased from 1.53 to 2 per cent. in the one case, and in the other from 1.3 to 1.86, the combined carbon shows practically no alteration. Further, as the other elements are practically constant, it may be assumed that this table shows the effect of increasing silicon, and whilst the first part of the table presents practically no difference in the average results from bars with from 1.67 to 2 per cent. of silicon, the second part shows a decrease in the strength as the silicon increases. This, therefore, does not confirm the results contained in the first part of the table obtained with bars of varying silicon content, and would point to some condition of the iron, apart from the analyses, which has a greater effect on the results of the tests. Also from the fact that the percentage of combined carbon has not been reduced in spite of the addition of one-third more silicon, it would further show

TABLE II.—*Tensile Tests with Increasing Silicons.*

Mark.	Analysis.							Actual Silicon added.	Diameter of Test-bar at Fracture.	Tensile Strength per Square Inch.		
	T. C.	G. C.	C. C.	Si.	S.	P.	Mn.			Machined from 1 inch.	Tons.	Mean of Sound Bars.
16	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Inch.	14.03	...	
17	3.56	2.98	0.58	1.53	0.11	1.19	0.90	None	$\frac{3}{4}$	13.48*	...	
18	"	"	"	"	"	"	"	"	"	"	13.75	
28	3.57	3.04	0.53	1.67	0.106	1.20	0.85	0.14	"	"	14.72	
29	"	"	"	"	"	"	"	"	"	"	15.31	
30	"	"	"	"	"	"	"	"	"	"	14.59	
31	3.56	3.00	0.56	1.65	0.075	1.20	0.87	0.12	"	"	15.38	
32	"	"	"	"	"	"	"	"	"	"	...	
33	"	"	"	"	"	"	"	"	"	"	15.46	
34	3.58	2.99	0.59	1.88	0.106	1.17	0.90	0.33	"	"	15.22	
35	"	"	"	"	"	"	"	"	"	"	14.54	
36	"	"	"	"	"	"	"	"	"	"	...	
37	3.57	2.98	0.57	2.00	0.09	1.17	0.81	0.47	"	"	14.88	
38	"	"	"	"	"	"	"	"	"	"	...	
39	"	"	"	"	"	"	"	"	"	"	15.47	
43	3.56	2.98	0.58	1.30	0.077	0.59	0.68	None	"	"	15.67	
44	"	"	"	"	"	"	"	"	"	"	15.68	
45	"	"	"	"	"	"	"	"	"	"	14.74†	
52	3.59	3.05	0.54	1.46	0.073	0.84	0.65	0.16	"	"	14.28	
53	"	"	"	"	"	"	"	"	"	"	14.42	
54	"	"	"	"	"	"	"	"	"	"	15.03	
55	3.56	3.02	0.54	1.72	0.072	0.78	0.66	0.42	"	"	14.57	
56	"	"	"	"	"	"	"	"	"	"	14.94	
57	"	"	"	"	"	"	"	"	"	"	14.04	
58	3.56	3.00	0.58	1.86	0.076	0.70	0.65	0.56	"	"	13.97	
59	"	"	"	"	"	"	"	"	"	"	13.78	
60	"	"	"	"	"	"	"	"	"	"	13.47	

\* Slight flaws.

† Flaw.

that silicon alone is not the only factor in the conversion of combined carbon to graphite. One point is very clear, namely, that with the increase of silicon the crystals of the iron have also increased in size; but these are also affected by the cooling conditions which are independent of the analysis. The tensile test-bars were cast as per the sketch (Fig. 1),

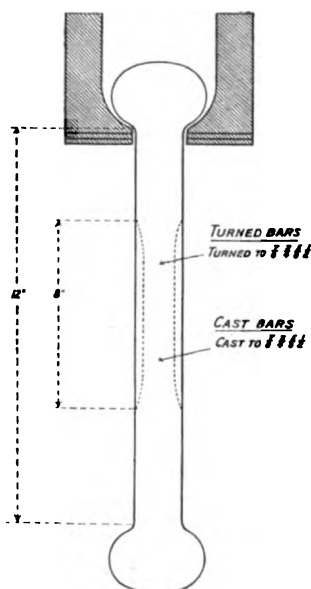


FIG. 1.

1 inch in diameter and 12 inches long, with nobs cast in the bar as shown, and fitted into a properly prepared socketed grip in the testing machine, thus causing a perfectly straight pull.

#### TRANSVERSE BENDING TESTS.

Table III. gives the transverse tests, and in this case also it will be noticed that whilst the breaking weight of the transverse test-bars shows a slight variation, when the latter are worked out on the exact section of the bar to the moment of resistance, there is very little variation in the tests obtained

TABLE III.—*Transverse Tests with increasing Silicons.*

Mark.	Analysis.							Actual Per-centage of Silicon added.	Size of Test-bar at Fracture.		Transverse, 3 Ft. 0 In. Centres.		Deflection.		Moment of Resistance.	
	T. C.	G. C.	C. C.	Si.	S.	P.	Mn.				Inches.	Mean Inches.	f=	Mean.		
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	None	Inches.	As cast	Cwts.	Mean Cwts.				
H	3.56	2.98	0.58	1.53	0.110	1.19	0.90	None	2.05 x 1.050		34	...	0.344	...	20.804	...
H	"	"	"	"	"	"	"	"	2.09 x 1.040	"	35	...	0.344	...	20.802	...
F	"	"	"	"	"	"	"	"	2.075 x 1.100	"	35	...	0.344	...	19.963	...
F	"	"	"	"	"	"	"	"	2.095 x 1.100	"	35	34.75	0.312	0.336	19.573	20.283
A	3.56	3.03	0.53	1.65	0.098	1.19	0.85	0.12	2.15 x 1.115	"	39	...	0.487	...	20.430	...
A	3.57	3.04	0.53	1.67	0.106	1.20	0.85	0.14	2.11 x 1.138	"	38	38.5	0.375	0.386	20.430	20.430
B	3.56	3.00	0.56	1.65	0.075	1.20	0.87	0.12	2.08 x 1.098	"	37	...	0.344	...	20.833	...
B	3.56	3.00	0.56	1.65	0.075	1.20	0.87	0.12	2.14 x 1.140	"	36	36.5	0.314	0.329	18.618	19.725
C	3.56	3.00	0.56	1.65	0.075	1.20	0.87	0.12	2.11 x 1.082	"	34	...	0.314	...	19.056	...
C	3.58	2.99	0.59	1.88	0.10	1.17	0.80	0.33	2.092 x 1.112	"	36	36.0	0.344	0.329	19.590	19.523
D	3.58	2.99	0.59	1.88	0.10	1.17	0.80	0.33	2.095 x 1.072	"	35	...	0.329	0.359	20.084	20.796
D	3.57	2.98	0.57	2.00	0.09	1.17	0.81	0.47	2.092 x 1.090	"	38	36.5	0.390	0.359	21.509	20.796
E									2.086 x 1.050	"	30	30.0	0.314	0.314	...	17.078
M	3.56	2.98	0.58	1.30	0.077	0.59	0.68	None	2.0727 x 1.048	"	32	...	0.329	...	19.188	...
O	3.59	3.06	0.54	1.46	0.073	0.84	0.65	0.16	2.043 x 1.062	"	31	31.5	0.329	0.329	19.062	19.125
I	3.56	3.02	0.54	1.72	0.072	0.78	0.66	0.42	2.057 x 1.030	"	28	...	0.281	...	17.346	...
I	3.56	3.02	0.54	1.72	0.072	0.78	0.66	0.42	2.071 x 1.026	"	29	28.5	0.314	0.347	17.793	17.669
J	3.56	3.00	0.58	1.86	0.072	0.70	0.65	0.56	2.075 x 1.036	"	30	29.5	0.344	0.350	18.089	...
J	3.56	3.00	0.58	1.86	0.072	0.70	0.65	0.56	2.084 x 1.028	"	29	29.5	0.359	0.350	17.537	17.813
K	3.56	3.00	0.58	1.86	0.072	0.70	0.65	0.56	2.087 x 1.024	"	27	...	0.314	...	16.344	...
K	"	"	"	"	"	"	"	"	2.088 x 1.030	"	28	27.5	0.329	0.321	16.833	16.888

TABLE IV.—Comparative Transverse Tests as Cast and as Machined.

Distinctive Mark.	Machined.	Analysis.						Size of Bar at Fracture.	Tested.	Transverse.		Deflection.		Moment of Resistance per Square Inch.	
		T. C.	G. C.	C. C.	Si.	S.	P.	Mn.		Cwts.	Mean Cwts.	Inches.	Mean Inches.	Tons.	Mean Tons.
F		Per Cent. 3.56	Per Cent. 2.98	Per Cent. 0.58	Per Cent. 1.53	Per Cent. 0.110	Per Cent. 1.19	Per Cent. 0.90	As cast	34	34.5	0.344	0.344	20.804	20.803
F	G	"	"	"	"	"	"	"	"	35	34.5	0.344	0.344	20.802	20.803
H	G	"	"	"	"	"	"	"	Machined	34	33.5	0.437	0.437	22.960	22.960
H		"	"	"	"	"	"	"	"	33	33.5	0.437	0.437	22.275	22.612
		"	"	"	"	"	"	"	As cast	35	35.0	0.344	0.344	19.963	19.963
		"	"	"	"	"	"	"	"	35	35.0	0.312	0.312	19.573	19.763
M		Per Cent. 3.54	Per Cent. 2.98	Per Cent. 0.56	Per Cent. 1.30	Per Cent. 0.077	Per Cent. 0.59	Per Cent. 0.68	As cast	32	31.5	0.327	0.327	19.188	19.188
O	L	"	"	"	"	"	"	"	"	31	31.5	0.327	0.327	19.062	19.125
	N	"	"	"	"	"	"	"	Machined	24	25.0	0.375	0.375	21.273	21.273
		"	"	"	"	"	"	"	"	26	25.0	0.468	0.421	22.862	22.067
G		Per Cent. 3.71	Per Cent. 3.05	Per Cent. 0.64	Per Cent. 1.34	Per Cent. 0.09	Per Cent. 1.12	Per Cent. 0.60	As cast	35	35.0	0.352	0.352	20.09	20.09
G		"	"	"	"	"	"	"	"	34	34.0	0.305	0.305	19.8	19.8
G	G	"	"	"	"	"	"	"	"	33	34.0	0.328	0.328	19.1	19.9
		"	"	"	"	"	"	"	Machined	...	34.0	...	0.461	...	22.9

from those bars with increased percentages of silicon, whilst the second part of the table shows that increasing amounts of silicon have decreased the strength, which confirms the tensile tests in this respect. In this case, also, whilst the percentages of combined carbon are not very materially altered, the fractures in the 2 inch by 1 inch test-bars show increasing openness as the silicon increases from 1·30 to 2·00 the bars with the higher percentage showing the most open fracture.

Table IV. shows the difference in tests obtained from the transverse test-bars as cast and as machined, indicating a great improvement in the strength of the machined bar. It has generally been assumed that the skin of the test-bar increases the strength, but this investigation has proved that quite the contrary is the case, and the results have been confirmed in actual practice since these tests were made.

Whilst making these tests, also, it was thought desirable to see what position of the transverse test-bar gave the best results. The bars in each moulding-box were cast in a different position, namely, (F) cast flat with no inclination, (G) cast on edge with no inclination, and (H) cast on edge with an inclination of 3 inches in 3 feet. The results are given in Table V., and do not show that there is any material difference in the bars cast on edge. It was shown by the author in May 1906, in his paper read before the Institute, that the transverse test-bar tested with the "fin" up—that is, the "fin" in compression and the lower part or sounder part in extension—invariably gave the best results.\*

#### CASTING TEMPERATURE.

There has been a good deal of discussion upon the temperature at which cast iron should be poured into the mould, a medium casting temperature being considered by some to give the best results. To prove this, 10 cwts. of iron was taken from the cupola and poured into five sets of moulds. The first mould was poured at 3.40 P.M., well within two minutes of being tapped from the cupola, the second at

\* *Journal of the Iron and Steel Institute*, 1906, No. I. p. 91 (Table A).

TABLE V.—*Transverse Tests from same Ladle under Different Conditions of Casting.*

	Metal from One Ladle.							Transverse 2' x 1' x 3' 0" Centres.		Deflection.		Moment of Resistance.	
	T. C.	G. C.	C. C.	Si.	S.	P.	Mn.	Cwts.	Mean Cwts.	Inches.	Mean Inches.	Tons.	Mean Tons.
	Per Cent. 3.71	Per Cent. 3.06	Per Cent. 0.66	Per Cent. 1.34	Per Cent. 0.09	Per Cent. 1.12	Per Cent. 0.60						
F	a	...	...	...	...	...	...	35	...	0.344	...	21.1	...
	b	...	...	...	...	...	...	28	...	0.258	...	17.0	...
	c	...	...	...	...	...	...	28	30.33	0.266	0.289	18.5	18.9*
	d	...	...	...	...	...	...	...	...	...	...	...	...
G	a	...	...	...	...	...	...	35	...	0.352	...	20.9	...
	b	...	...	...	...	...	...	34	...	0.302	...	19.8	...
	c	...	...	...	...	...	...	33	34.00	0.328	0.327	19.1	19.9†
	d	...	...	...	...	...	...	...	34.0	...	0.461	...	22.9§
H	a	...	...	...	...	...	...	34	...	0.312	...	19.9	...
	b	...	...	...	...	...	...	31	...	0.386	...	19.5	...
	c	...	...	...	...	...	...	30	31.66	0.297	0.315	19.2	19.5
	d	...	...	...	...	...	...	...	...	...	...	...	...

\* Tested as cast. Cast flat, with no inclination.  
† Tested as cast. Cast on edge, with no inclination.  
‡ Tested as cast. Cast on edge, with an inclination of 3 inches in 3 feet 0 inch.  
§ Tested as cast. Cast flat, with no inclination.  
|| Tested as cast. Cast on edge, with no inclination.

3.45 P.M., the third at 3.50 P.M., the fourth at 3.55 P.M., and the fifth at 4 P.M., showing a five minutes' interval between each mould. The tests shown in Table VI. clearly indicate that the mould poured first gave the best results.

### MOMENT OF RESISTANCE TEST.

It will be noticed that the transverse tests are all worked out to the moment of resistance in order to see what the result of a given test would be on the exact section of the transverse bar. In Table III. it will be seen that each bar is slightly over the 2 inch by 1 inch dimension, and the area therefore of each test-bar varies, as do also the tests, but when worked out to the moment of resistance based upon Unwin's formula:—

W=Breaking weight in tons,

L=Length of the bar between supports in inches,

b=Breadth of bar in inches,

d<sup>2</sup>=Depth of bar squared in inches,

M=Bending moment  $= \frac{WL}{4}$ ,

Z=Modulus of section  $= \frac{bd^2}{6}$ ,

$f \times \frac{b \cdot d^2}{6}$  = Moment of resistance of bar to breaking,

$f \times \frac{b \cdot d^2}{6} = \frac{W \cdot L}{4}$

Then  $f = \frac{W \cdot L \cdot 6}{4bd^2} = \frac{1.5WL}{bd^2}$ .

The tests show that whilst the transverse bars themselves may slightly vary, when worked out to this test based on the exact area, there is very little variation with the increasing silicon in one case, and a fall in the strength in the other. On the other hand, in the case of the bars tested as cast and as machined, whilst the machined bars may show if anything a less favourable result, if the breaking weight of the bar is based upon the exact area and worked out to the moment of resistance, it gives upwards of 10 per cent. better breaking load and 40 per cent. better deflection.

Transverse test-bars in Britain are of two sections, 2 inches by 1 inch and 1 inch by 1 inch, and the supports vary from 12 inches to 36 inches, and whilst it is not difficult to obtain



TABLE VI.

Tensile Mark.	Transverse Mark.	One Ladle of Iron cast at different Temperatures.							Time of Casting.	Tensiles.		Transverse.		Deflection.		Moment of Resistance.		
		T. C.		G. C.	C. C.	Si.	S.	P.		Mn.	Tons.	Mean Tons.	Cwts.	Mean Cwts.	Inches.	Mean Inches.	Tons.	Mean Tons.
		Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.										
50		3.76	3.10	0.66	1.30	0.114	1.14	P.M. 3.40	16.19	...	...	...	...	...	...	...	*	
51		...	...	...	...	...	...	...	16.13	...	...	...	...	...	...	...	*	
52		...	...	...	...	...	...	...	16.4	...	...	...	...	...	...	...	*	
53		...	...	...	...	...	...	...	16.32	16.21	...	...	...	...	...	...	*	
	A	...	...	0.66	...	...	...	...	...	...	32	...	0.375	...	...	20.3	*	
	A	...	...	...	...	...	...	...	...	...	33	...	0.3125	...	...	20.3	*	
	A	...	...	...	...	...	...	...	...	...	33	32.66	0.344	0.343	...	20.6	20.4*	
54		...	...	0.66	...	...	...	3.45	14.60	...	...	...	...	...	...	...	†	
55		...	...	...	...	...	...	...	15.17	...	...	...	...	...	...	...	†	
56		...	...	...	...	...	...	...	14.08	...	...	...	...	...	...	...	†	
57		...	...	...	...	...	...	...	15.30	14.79	...	...	...	...	...	...	†	
	B	...	...	0.66	...	...	...	...	...	...	32	...	0.344	...	...	19.6	†	
	B	...	...	...	...	...	...	...	...	...	32	...	0.344	...	...	20.5	†	
	B	...	...	...	...	...	...	...	...	...	29	31.00	0.352	0.347	...	18.47	19.52†	



an approximate comparison between these bars, it is very difficult to do so between British transverse bar tests and those of other countries. This difficulty could, however, easily be overcome by adopting the moment of resistance, which depends upon the section of the test-bar and the length between supports to express the quality of the material, thus rendering tests of all sizes of transverse test-bars comparative.

#### CONCLUSIONS.

1. The best tensile and transverse tests are obtained from bars which have been machined.

2. Transverse test-bars cast on edge and tested with the "fin" in compression give the best results in testing.

3. The ordinary method of expressing the results of a transverse test is not as useful an indication of the quality of the test-piece as the statement of the actual moment of resistance.

4. The use of high-grade ferro-silicon in the foundry is of no commercial value.

5. Cast iron gives the best results when poured as hot as possible.

The author wishes to thank Messrs. William Gray & Co., of West Hartlepool, for placing their Central Marine Engine Works Foundry at his disposal for these tests; and at the same time Mr. John B. Williams, their assistant manager, for the interest taken in the experiments; as well as his late colleague, Mr. George H. Hewson, for assistance in the analyses.

*DISCUSSION.*

Professor TURNER (Birmingham) said that Mr. Adamson had given some very interesting information bearing on the subject of tests for cast iron. He had given them in some cases facts which were in accordance with their experience, and in other cases he had given them conclusions on vexed subjects which might possibly be called into question by other workers. In relation to tensile tests, he (Professor Turner) thought they were certainly correct in saying that turned test-pieces gave best results, if they used the word "best" in the sense of the word "trustworthy." The form of clutch which was shown in the diagram was undoubtedly a good one. A circular test-bar should be held so as to give a perfectly straight pull, and should be turned in the central portion, as this was the best form for tensile tests. They had to take the utmost care in dealing with cast iron to get a straight pull, owing to the very low ductility of the material. Rectangular bars gave them irregular results. Sometimes higher results were obtained by testing bars with the skin on, although they were not so trustworthy. It was a curious fact, to which other observers had called attention, that when transverse bars were cast in the position mentioned by the author, higher results were obtained than if cast in any other position. In reference to the use of higher grade ferro-silicon there had been considerable difference of opinion, and he thought they would have to leave Mr. Outerbridge and Mr. Adamson to fight out that question. Mr. Outerbridge had given a number of examples in which a great advantage had resulted from adding a small quantity of high grade ferro-silicon just before casting. He (the speaker) had never advocated it, nor had he found it to be advantageous with English foundry mixtures. It was far too expensive to use even at its present price, and it was so powerful a medicine that, with slight variations from the correct quantity, the result was unsatisfactory. If, however, they managed to add high grade ferro-silicon in just the right quantity, and at the right time, they got good results. Otherwise, it would be far better to leave it out. He was very interested in the last conclusion, namely, that cast iron gave the best results when poured as hot as possible. The question was, at what temperature should cast iron be poured so as to give the best results? Mr. Adamson gave them a good deal of evidence in the paper in favour of his conclusions. As he knew there were members in that room who had had experience on that point, and who held different views, they would perhaps care to give the results of their experience.

Mr. ADAMSON, in reply, stated he was sorry the paper had not been more fully discussed, for he was aware, as Professor Turner had stated, that some of the conclusions were not in agreement with other workers. He was obliged to Professor Turner for his remarks. When he (the author) stated that higher results were obtained from machined bars, he meant higher tests as well as more trustworthy ones, and it might even

be possible that under certain conditions test-bars of some very *soft* irons might not show such different results when machined as the bars now in question. Foundry conditions in regard to cast iron varied so very much that it was impossible to lay down definite rules which would apply in every case that the author had on several occasions pointed out. He (the author) believed he was the first to point out the best position for testing the transverse bar.

As to the use of ferro-silicon of high grade, he thought Professor Turner and he were at one, for not only was the present price prohibitive for foundry work, but the oxidation loss was excessive, and each addition of 1·00 per cent. silicon to the iron in this way would cost anything from 10s. to 20s. per unit per ton, whilst any benefits from using ferro-silicon could be obtained at a much less cost.

## THE CONSTITUTION OF CARBON-TUNGSTEN STEELS.

By THOMAS SWINDEN, B.MET. (SHEFFIELD).

### INTRODUCTION.

THE following researches are a continuation of the work reported in a previous paper on carbon-tungsten steels,\* together with some further considerations of the phenomena observed therein.

The series of nine crucible steels ranged from 0·14 to 1·24 per cent. carbon, with tungsten constant about 3 per cent. Amongst other things, the heating and cooling curves were very thoroughly examined, particular attention being paid to the influence of initial temperature in cooling. As the present work is based on the results of this thermal investigation, a brief summary of the conclusions obtained therefrom will be included. For fuller details, together with some considerations on the work of previous investigators, the original paper should be consulted.

It was shown that:—

1. Below a certain initial temperature the steels show recalescence points on cooling, precisely as do carbon steels.

2. Heating beyond this definite initial temperature produces a marked lowering of Ar1 to a definite low point, occurring at a temperature determined by the tungsten content of the steel. Ar2, when found free in the normal curves, is practically unaffected by the initial temperature; whilst Ar3 is apparently gradually suppressed in its normal position, but reappears in a relatively similar position above the lowered Ar1. In steels with carbon content from 0·35 to 0·90, in which Ar3.2 is a single point, this is lowered on increasing the initial temperature and follows Ar1, giving

\* "Carbon-tungsten Steels," *Journal of the Iron and Steel Institute*, 1907, No. I. pp. 291-324.

two low points strongly resembling the normal Ar3.2, and Ar1. With 0.9 per cent. carbon and higher, a single point is given at the low temperature, when cooled from beyond the lowering temperature.

3. As the carbon increases, higher initial temperature is required to produce a lowering effect on the points, but the lowered Ar1 is practically constant throughout the series at 570° C. This marks the complete lowering effect of 3 per cent. of tungsten.

4. Microscopic analysis confirms the cooling curves, showing that the eutectic ratio is practically unaltered. The structures generally resemble those of carbon steels, but are much finer in pattern.

5. It is conclusively shown that rate of cooling does not affect the position of the points, at any rate of Ar1, when the initial heating has been to beyond the "lowering temperature."

From the foregoing, it was suggested that at Ac1 on heating, a change of similar nature to the change in carbon steels occurs, and then, at the lowering temperature, a further change sets in, in which the tungsten is involved. The steel reverts to its normal condition at the low point about 570°.

Fig. 1 is a diagram of the position of the recalescence points, and illustrates clearly the above-mentioned phenomena. Line LT marks the initial temperature first influencing the points, but, especially as the carbon increases, considerable soaking is necessary to complete the lowering effect. In brief, if the steel is heated to any temperature below LT, a cooling curve precisely as for a carbon steel results. Immediately LT is overstepped, the form of the curve is changed, resulting ultimately in Ar1 occurring at 570° instead of 680°. Line NP marks out the temperature of the lowered Ar1 points.

If then, after cooling, say, from 1200°, and getting a low point curve, the steel is heated to below the LT and cooled, the normal curve is recovered. Some differences were pointed out between the inferences drawn from the above work, and the theories previously advanced by M. Osmond and Professor Carpenter.

The present research was carried out in order to supple-

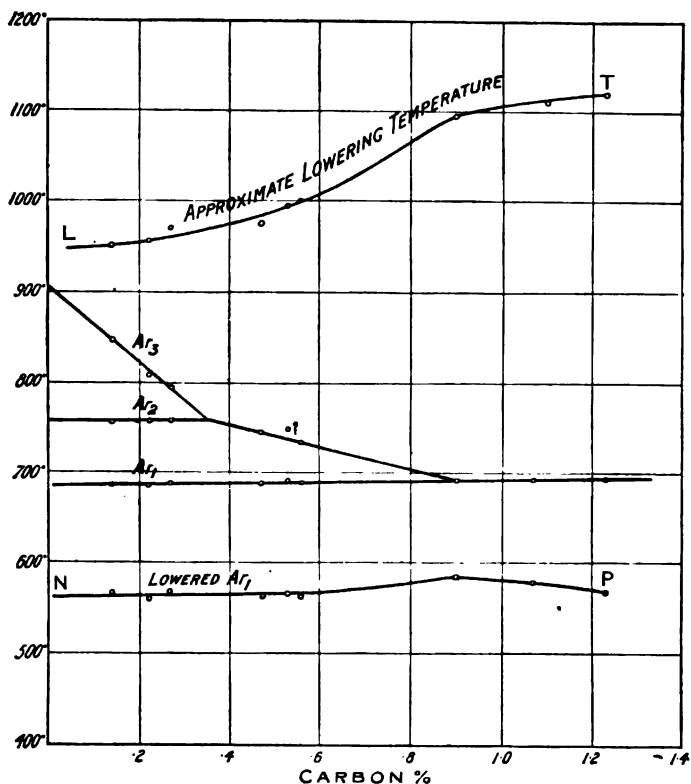


FIG. 1.

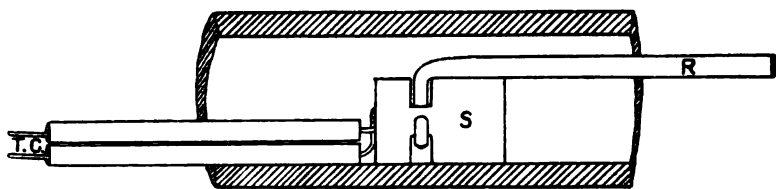


FIG. 2.

ment the thermal data, with microscopical examination of heat-treated specimens.

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## MATERIAL AND METHODS EMPLOYED.

For this work three of the steels previously worked upon were employed, and the complete analyses are given in Table I.

TABLE I.—*Analyses of Steels Used.*

Mark.	Wolfram.	Carbon.	Silicon.	Manganese.	Sulphur.	Phosphorus.	Aluminium.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
920	3·17	0·57	0·078	0·080	0·054	0·010	0·011
965	3·08	0·89	0·039	0·093	0·040	0·012	0·014
719	3·02	1·24	0·047	0·220	0·017	0·021	nil

Two distinct sets of experiments have been carried out—viz. (1) quenching and (2) air cooling.

TABLE II.—*Details of Quenching Experiments.*

Series.	Steel.	Time Heating Up.	Initial Temperature.	Time Soaking at Initial Temperature.	Time in Cooling.	Quenching Temperature.
		Minutes.	Degrees C.	Minutes.	Minutes.	Degrees C.
A	920	5	950±5	10	...	950
	965	5	1000±5	10	...	1000
	719	8	1000±5	10	...	1000
B	920	5	950±5	10	15	740
	965	8	980±5	10	15	740
	719	10	1000±5	10	25	745
C	920	5	940±5	10	20	620
	965	5	980±5	15	20	615
	719	5	980±5	20	25	620
D	920	10	1230±10	15	...	1235
	965	10	1250±10	15	...	1260
	719	10	1250±10	15	...	1260
E	920	10	1220±10	10	60	630
	965	10	1220±10	10	45	650
	719	45	1245±10	10	45	635
F	920	10	1210±10	35	35	480
	965	15	1230±10	40	40	487
	719	10	1250±10	40	40	480

*Quenching Experiments.*—The pieces for microsections were machined to the shape shown in Fig. 2. They were  $\frac{1}{2}$ -inch diameter, and  $\frac{3}{4}$ -inch long over all. A nick was put in about  $\frac{3}{16}$ -inch from one end, so that the actual specimen examined was  $\frac{3}{16}$ -inch thick by  $\frac{1}{8}$ -inch diameter, the latter being knocked off after quenching.

The specimens were examined on the flat face, and then ground under water, half-way through, and examined on the cross-section. The heating was carried out in a porcelain tube, with the ends plugged during heating, and the furnace was coke fired. The face surface of the section was in direct contact with a thermo-couple, the identical apparatus used in taking the cooling curves being also used here. The temperatures given can therefore be taken as absolutely in accordance with those of the cooling-curve diagram.

The precise heat treatment given each section previous to quenching is given in tabular form in Table II., and is also shown diagrammatically in Fig. 3.

Only one specimen was in the furnace at a time.

The specimens were quenched in brine at about 7° C., and since the cooling is not instantaneous it may be well to note that the structures will represent the constitution existing at the quenching temperature, modified, possibly to a very slight degree, by the changes normal to slow cooling.

TABLE III.—*Hardness Tests on Quenched Steels.*

Mark.	Hardness.	Mark.	Hardness.
920A	7 barely.	920D	7 nearly.
965A	7 full.	965D	7 nearly.
719A	7 full.	719D	7 just.
920B	7 nearly.	920E	6 full.
965B	7 just.	965E	7 just.
719B	7 full.	719E	7 just.
920C	5 full.	920F	5
965C	5 full.	965F	5 full.
719C	6 nearly.	719F	5 full.

Before considering the microstructures it may be of interest

to give the hardness-test results, as giving some practical idea of the influence of the above treatments.

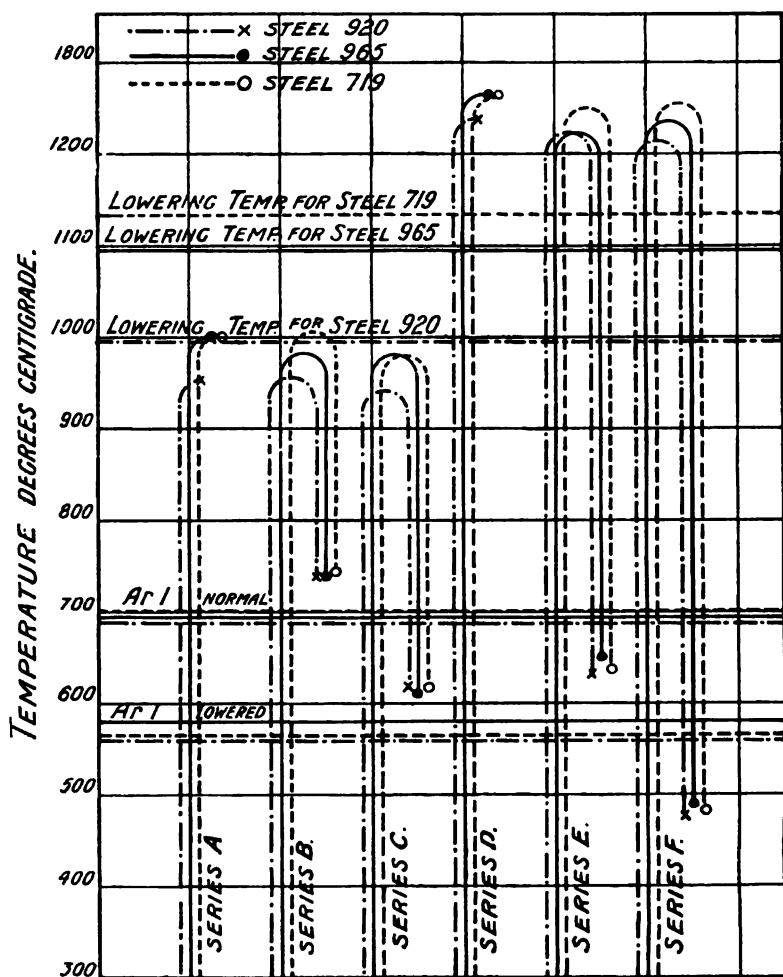


FIG. 3.—Quenching Experiments.

The figures represent mineralogical hardness, according to Moh's scale, and are given in Table III.

It will be seen that the A, B, C series have given hardness

figures exactly as would be expected for carbon steels similarly treated. The D series, it will be noted, are not quite so hard as A, but the difference is small. Series E bear out in a conclusive manner the suggestions made when considering the cooling curves. Quenched at practically the same temperatures as series C, but after previous heating to beyond the lowering temperature, the former are still quite hard, whilst the latter are completely softened. The observation is not altogether new. In Hadfield's paper, "Alloys of Iron and Tungsten,"\* Osmond describes experiments with a steel containing 0.42 per cent. carbon and 6.22 per cent. tungsten. This steel was soft after heating to 830° and quenching at 630°, but very hard when heated to 1310° and quenched at 555°. The reason is made clear on seeing the cooling curves, since in the second case the quenching temperature is still above the recalescence point shown on cooling.

The microstructures have been carefully examined after progressive etching in nitric, picric, and hydrochloric acids, and with iodine. The sections were entirely repolished between each reagent. 5 per cent. picric acid in alcohol was adopted as most suitable for a general examination, since this is more easily controlled than the 2 per cent. nitric acid in alcohol, and was therefore better suited for comparative etching. 10 per cent. hydrochloric acid in alcohol was used to advantage in several cases as will be seen later, and iodine tincture was also called upon to furnish a further means of comparing the structures.

The photomicrographs have been taken by means of the Zeiss apparatus installed at the Sheffield University. The magnification of the quenched series is in general 300 diameters, and are reduced a little as reproduced, and most have also been taken at 1000 diameters. The cast, rolled, and air-cooled structures were photographed at 150 diameters.

Fig. 1 (Plate X.) shows steel 965 as cast, whilst Figs. 2, 3, and 4 represent respectively steels 920, 965, and 719 after rolling. These are etched in nitric acid in alcohol, and attention is again drawn to the fact that the eutectic ratio is practically unaltered.

\* *Journal of the Iron and Steel Institute*, 1903, No. II.

The descriptions found in Table IV. refer to picric acid etching, at a magnification of 300 diameters. In these descriptions the ordinary terms ferrite, pearlite, cementite, &c., have been used. This is merely for simplicity in giving some idea of the appearance of the microstructure and is not intended to define a composition or constitution. The term martensite has been used as referring to the hard dark etching constituent of hardened steels.

Replacing nitric acid with picric resulted in slower etching, but the structures were essentially the same. Thus, 920D gave the same result in three minutes in nitric acid as in ten minutes in picric, of similar strength.

The martensite in specimens A, B, D, and E was, in every case, untouched by hydrochloric acid in alcohol. In the B series occasional troostitic areas were developed, and in D and E the cellular boundaries could be distinguished in diaphragmed light. Otherwise ten or fifteen minutes in the hydrochloric acid bath had no visible effect. As an illustration of this, Fig. 23 (Plate XIV.) shows section 719E after fifteen minutes in hydrochloric. The large polygonal cells have been marked out, and the section is pitted, but the structure is not developed. The C and F specimens were easily attacked with hydrochloric acid, five minutes' treatment developing a structure similar to that obtained by the picric etching.

Figs. 23 and 24 (Plate XIV.) afford a very striking comparison. They represent respectively sections 719E and 719C etched simultaneously in the hydrochloric bath. Reference to Table II. will show that these structures represent steel 719, quenched at practically the same temperature in both cases, but the former after cooling from 1245°, and the latter from 980°. The one consists of unetched martensite, with some cementite, and the other of normal pearlite and excess cementite. Figs. 25 and 26 (Plate XIV.) illustrate iodine etching on specimens 719A and 719D, and are comparable with Figs. 17 and 20 (Plate XIII.), representing picric etching.

*Some Comparisons of Microstructures.*—Having outlined the general characteristics, the sections will now be considered in

TABLE IV.—*The Microstructures in Brief.*

Micro. No.	Mark.	Initial Temperature. Degrees C.	Quenching Temperature. Degrees C.	Minutes Etching.	Microstructure.
5	920A	950	950	6	Almost structureless brown mass of martensite.
11	965A	1000	1000	4	Extremely fine dark martensite.
17	719A	1000	1000	4	Dark ground as 965A with occasional speck of cementite.
6	920B	950	740	5	The ferrite has begun to segregate in a ground of martensite. Occasional troostite areas.
12	965B	980	740	4	Even dark hardenite, practically structureless.
18	719B	1000	745	4	Ground dark hardenite; fine specks of cementite in considerable quantity.
7	920C	940	620	$\frac{1}{2}$	Pearlite and ferrite, completely segregated.
13	965C	980	615	$\frac{1}{2}$	Normal pearlite.
19	719C	980	620	$\frac{1}{2}$	Normal pearlite, interspersed with cementite. The latter occasionally segregated into somewhat large masses.
8	920D	1235	1235	10	Light brown mass, wavy martensite.
14	965D	1260	1260	8	Rather pale brown, with occasional markings of paler tint; latter not so distinct as would appear from photograph.
20	719D	1260	1260	7	Brown martensite with small specks of a lighter tint.
9	920E	1220	630	6	Even martensite, very similar to 920D, but not so angular.
15	965E	1220	650	5	Even martensite, crystal junctions well defined.
21	719E	1245	645	4	Fine cementite marks out large cells of martensite. Little free cementite within cells.
10	920F	1210	480	$\frac{1}{2}$	Pearlite and ferrite in angular pattern. Segregation complete.
16	965F	1230	487	$\frac{1}{2}$	Fine laminated pearlite, occasional troostitic areas.
22	719F	1250	480	$\frac{1}{2}$	Large angular cells of laminated pearlite, in walls of cementite.

selected groups, the object being to point out the bearing of the microstructures on the suggestions advanced on the cooling curves.

*The A, B, C Series.*—These sections are all quenched after heating to below the “lowering temperature,” and present no special feature beyond the ordinary structures obtained from carbon steels. 920B shows segregated ferrite; and in 719B the cementite has lost its cellular structure. This latter, together with 719A, would apparently prove that the cementite has been in complete solution at 1000°. In the C series the steels have completely reverted to the “soft” normal state.

*The D, E, F Series.*—The E steels are particularly interesting. 920E, quenched so low as 630°, well below the normal Ar1 point, is found, after most careful examination, to differ only very slightly from 920D quenched at 1235°. Both are hard, and consist of only one constituent. No free ferrite is seen in 920E, although the cooling was so slow as to take sixty minutes from 1220° to 630°. This is due, no doubt, to the fact that the quenching temperature is still above the lowered Ar3.2 point.

All the E sections were found to confirm microscopically the hypothesis that the peculiar constitution above the lowering temperature was maintained until the lowered points were reached, irrespective of rate of cooling. Section 719E is important as evidencing the movement of free cementite. Quenched at 645° after an initial heating to 1245°, some cementite has undoubtedly separated as thin cell walls and specks.

The F sections present, so far as can be judged, ferrite, laminated pearlite, and cementite in perfectly normal condition. The structures are extremely coarse, being considerably worse in this direction than the structures “as cast.”

Considering the series A and D, the differences are not so marked as one might be led to expect from the remarkable differences found on cooling from these initial temperatures. It may, however, be remarked that, apart from structural differences, the A specimens etch considerably quicker than the D. Thus 719A quickly decolorised iodine, and after one application showed well-developed martensite; whereas 719D was only very slowly attacked, and required three applications

to give a comparable effect. The two latter structures are illustrated in Figs. 25 and 26 (Plate XIV.). As previously noted, series E and C obviously differ in constitution. The B and E series, representing the structures immediately above the ordinary and the lowered points respectively, present considerable structural differences, notably with steel 719, but constitutional dissimilarity is not so apparent. A further series of quenched specimens are described later on p. 248.

*Résumé of Conclusions on the Quenched Specimens.*—The micrographic analysis affords, together with the hardness tests, perfect confirmation of the general facts governing the lowering of the recalescence points in tungsten steels previously detailed. The results show that the peculiar constitution formed on heating to beyond the lowering temperature is preserved irrespective of rate of cooling; whilst in a previous research (*loc. cit.*) it was shown that although the cooling was arrested for two and a quarter hours below the lowering temperature, the lowered change point was not raised in the slightest. Further, it was proved that, if after cooling from a high temperature and recording a low point, the steel was then heated to, and cooled from below the lowering temperature, the normal curve was regained. So, with the microsections, series F quenched below the low point give the ordinary constituents ferrite, pearlite, cementite found in the normal steels. A hypothesis on the nature of the change at the lowering temperature is given later.

#### AIR-COOLING EXPERIMENTS.

By "air cooling" it is implied that the sections were heated to the given temperature, and cooled freely in air. The three steels as used in the quenching experiments were also used here. The sections were  $\frac{1}{8}$ -inch diameter and  $\frac{3}{16}$ -inch thick. The heating was performed in the same tube furnace as for the quenched specimens, and temperatures determined by means of the same pyrometer.

The plan of operation was to take one section of each of the three steels (Nos. 920, 965, 719), place them flat, side by side, in the previously heated tube, and heat together for a



definite time at the temperature required. The specimens, which were set on a small asbestos pad, were then withdrawn, and cooled, face upwards, on an iron plate. The sections, being small, were cool enough to handle, two to three minutes after withdrawing from the tube. As will be seen from Table V.,

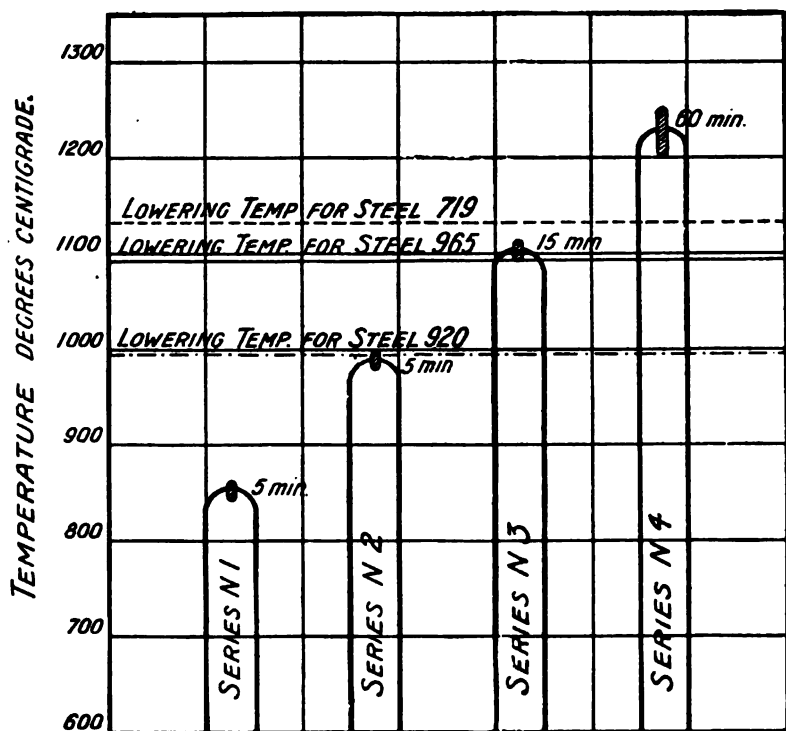


FIG. 4.—Air-cooling Experiments.

four temperatures were chosen, yielding in all twelve sections. The experimental scheme is also set out diagrammatically in Fig. 4.

The microstructures described and reproduced represent picric acid etching for about half a minute. The photomicrographs are magnified 150 diameters. A general description of the structures is given in Table VI.

TABLE V.—*Air-cooling Experiments.*

Set.	Mark.	Treatment.
N1	920N1 965N1 719N1	Heated slowly to 850° C., kept for five minutes, and cooled in air.
N2	920N2 965N2 719N2	
N3	920N3 965N3 719N3	
N4	920N4 965N4 719N4	Heated for sixty minutes between 1200° and 1250°, and then cooled in air.

TABLE VI.—*Microstructures of Air-cooled Sections.*

Micro. No.	Mark.	Cooled from	Microstructure.
27 31 35	920N1 965N1 719N1	850° C. " "	Very fine matrix of ferrite and pearlite. Fine sorbitic pearlite, occasional cementite specks. Sorbitic pearlite with cementite in fine specks. Cellular structure almost destroyed.
28 32 36	920N2 965N2 719N2	990° " "	Ferrite and pearlite, rather finer than 920N1. Dense sorbitic and troostitic pearlite. Black sorbitic ground mass, rather less excess cementite than 719N1.
29 33 37	920N3 965N3 719N3	1110° " "	Peculiar appearance. Quite uniform brownish black mass. Large areas resembling troostite; occasional fine yellow spots. No free ferrite. Similar to 965N2, but closer and more troostitic. Sorbitic pearlite, with very little free cementite.
30 34 38	920N4 965N4 719N4	1250° " "	Remarkable structure. Sharp angular bands of sorbitic and troostitic pearlite, interspersed with lighter martensite. Similar to 920N4 but in reversed proportions. Ground martensite, with angular troostite areas. Almost entirely martensite, with very occasional specks of troostite, and with peculiar small white areas, possibly cementite.

These sections are in full accord with the previous work, and are particularly interesting as furnishing some measure of the rapidity with which the changes take place on cooling. As the initial temperature is raised, the first point noted is

that the structure is rendered finer, and the pearlite more sorbitic. This statement seems somewhat strange in consideration of the general experience with carbon steels, but is supported in all the specimens here detailed.

In the section 920N3, heated to beyond its "lowering temperature," appear the first signs of an important change. Neither 965N3 nor 719N3, however, both of which have only just touched the LT, are greatly affected. In the final set, all cooled from well above the LT, there appear some remarkable structures. As seen from Figs. 30, 34, and 38 (Plates VI., VII., and VIII.), there is no doubt about the change in constitution here. As regards the constituents, the black is undoubtedly troostitic and sorbitic pearlite, and the lighter ground is of the same constituent which comprises the whole field in the respective steels quenched at this temperature. The author is able to make this statement with the utmost confidence, after a most careful examination by comparative etching in the different media. In the actual sections this constituent, designated martensite in Table VI., appears as a yellowish brown ground with darker martensitic markings. The apparent difference in appearance in this case to the respective quenched sections is owing to the fact that they were only etched for half a minute, in accordance with the other air-cooled sections. The similarity to the usual "austenite-martensite" structure is very interesting. A similar observation has been recorded by H. Le Chatelier,\* who speaks of this "pseudo-crystalline sorbite" as often occurring on the outer surface of quenched high carbon steel. He states: "The crystalline structure of this sorbite is exactly the same as that of martensite, because the change is limited during the first moments, and follows certain planes of crystallisation of the quenched metal."

The explanation is perfectly reasonable, and on these grounds the larger proportion of sorbite in the lower carbon steel (920N4) is easily understood. It should be remembered, however, that the carbon steel was quenched in water, whilst these tungsten steels were only air cooled.

\* H. Le Chatelier, discussion on Arnold and McWilliam, *Journal of the Iron and Steel Institute*, 1902, No. I.

A further point of interest is that in each of the N4 specimens the dark troostite was far more plentiful near the edge than in the centre of the specimen. Considering rate of cooling only, the reverse would be expected. A probable explanation would appear to be that advanced by Dr. Benedicks,\* who accounts for this on the ground that the formation of troostite is rendered more difficult by pressure. The pressure is afforded, of course, by the contraction stresses. This question of influence of pressure is one of considerable importance, as the many striking proofs given by Dr. Benedicks bear witness.

*Résumé of Conclusions on Air-cooled Specimens.*—The most interesting feature is the evidence which these experiments furnish as to the stability of the peculiar phase, which exists beyond the "lowering temperature," as judged by the changes occurring during air cooling.

The N4 series, which were heated to 1250° C., have all preserved a portion of the "martensite"—the proportion of the latter increasing with the carbon content of the steel—and, curiously enough, troostite preponderates near the edge. When heated to 1000° only, the steels show no sign of air hardening, and the fact that 3 per cent. of tungsten is sufficient to preserve a portion of the carbon in solution on air cooling from 1250° is, to the author's belief, a point not hitherto noted.

The experiments therefore confirm the view that the solution existing beyond the lowering temperature is very viscous in character compared with the pure carbon solution. In other words, the change occurring at the low point is slower in action than the ordinary change at the normal Ar1.

#### ELECTRICAL RESISTANCE DETERMINATIONS.

Determinations of electrical resistance have been carried out with a view to providing fresh data regarding constitution.

Following up earlier work by Johnson, Wedding, H. Le Chatelier, Barrett, Brown, Hadfield, Matthews, and other

\* Dr. Benedicks' Carnegie Research Report, *Journal of the Iron and Steel Institute*, 1908, No. II, p. 225.

investigators, Dr. Benedicks\* showed that the resistivity depended upon the amount of impurity in solution in the iron. Moreover, he advanced the hypothesis that the influence of an impurity on the resistivity followed a definite law, and was inversely proportional to the atomic weight of the impurity. That is to say, equi-atomic solutions of different impurities have the same electrical resistance.

This, then, forms a useful means of testing whether an impurity is present in solution or isolated in the iron. The determinations were carried out by means of a Thomson double bridge, using the standard method. Annealed, normalised, hardened, and specially treated specimens were examined, and each result reported is the mean of five or six closely agreeing determinations made along the length of the bar. Two sets of normalised bars gave results in perfect agreement.

The bars were 25·4 centimetres long and 0·798 centimetre diameter, thus giving 0·5 square centimetre area of cross-section. The length taken for a determination was 5·0 centimetres. The results are summarised in Table VII., where certain calculated values, to be referred to later, are also given.

#### DISCUSSION OF RESULTS, AND THEIR BEARING ON THE CONSTITUTION OF CARBON-TUNGSTEN STEELS.

*The Condition of Tungsten in the Normal Steels.*—The first point to consider is the form in which the tungsten exists in the normal tungsten steels, *i.e.* whether as carbide, double carbide, iron-tungsten compound, or metallic tungsten.

The view that tungsten exists in carbon-tungsten steels as a double carbide of iron and tungsten has been widely accepted, although the actual facts in support of this view are not very evident.

Arnold,† in 1894, stated: "Evidence has already been obtained of the existence of double carbides of manganese, chromium, nickel, and tungsten."

\* "Recherches physiques et physico-chimiques sur l'acier au carbone." Upsala, 1904.

† "The Physical Influence of Elements on Iron," *Journal of the Iron and Steel Institute*, 1894, No. I. p. 148.

TABLE VII.—*Electrical Resistance Values, in Microhms per Cubic Centimetre.*

Steel No.	Analysis.						Calculated Values.				Observed Values.		
	Carbon.	Tungsten.	Silicon.	Manga- nese.	Sulphur.	Phos- phrus.	Annealed.		Hardened.		Annealed.	Nor- malised.	Hardened.
							Tungsten not in Solution.	Tungsten in Solution.	Tungsten not in Solution.	Tungsten in Solution.			
											Per Cent.	Per Cent.	Per Cent.
924	0·144	3·25	0·044	0·065	0·055	0·010	(11·8)	(17·5)	13·1	18·75	17·31	16·63	19·24
922	0·218	3·24	0·050	0·071	0·050	0·010	(12·4)	(18·0)	15·0	20·76	17·50	17·63	19·33
923	0·27	2·92	0·027	0·170	0·014	0·018	(12·9)	(17·8)	16·5	21·56	...	17·63	20·20
921	0·48	3·11	0·060	0·075	0·060	0·010	16·7	22·2	22·3	27·73	18·87	19·12	23·87
981	0·53	3·18	0·033	0·140	0·035	0·012	16·7	22·2	23·8	29·19	18·40	18·46	25·64
920	0·57	3·17	0·078	0·080	0·064	0·010	17·0	22·7	25·1	30·55	18·56	19·98	26·68
965	0·89	3·08	0·039	0·093	0·040	0·012	17·5	23·0	33·2	38·46	17·64	18·76	36·6
964	1·07	3·09	0·040	0·055	0·042	0·012	16·3	22·0	37·8	43·16	16·97	18·43	38·70

Tungsten has also been compared with chromium by Hadfield,\* thus: "In the presence of carbon then, no doubt the tungsten increases the hardness, not in itself, but through its indirect action upon the carbon; it is a sort of 'irritant,' though probably not so powerful as chromium."

Osmond, in discussing Hadfield's paper (p. 109), said: "Chromium and tungsten, and probably molybdenum and vanadium, were not direct modifiers, but had as their object the maintenance of the carbon as hardening carbon under conditions of thermal treatment in which the carbon alone would separate into free carbide of little activity."

Dumas also spoke (p. 98) of the resemblance in character of the alloys of nickel, manganese, chromium, and tungsten.

Guillet† found a special constituent, presumably either a carbide of tungsten or a double carbide of iron and tungsten, in steels containing 0·2 per cent. carbon and above 7 per cent. tungsten, and in steels containing 0·8 per cent. carbon and above 5 per cent. tungsten. Below these percentages of tungsten the steels were "pearlitic." Guillet mentions a carbide,  $W_2C$ , prepared by Moissan in the electric furnace; also  $WC$ , and  $2Fe_3C, 3W_2C$  prepared by M. Williams. J. S. de Benneville and others have prepared a considerable number of iron-tungsten-carbon compounds by heating together the constituents at a white heat.

The only separation of a double carbide of iron and tungsten which has been noted is by Carnot and Goutal,‡ who obtained a residue with composition  $Fe_3C, WC$  by treating two steels of analysis: (1) tungsten, 6·6 per cent.; carbon, 2·0 per cent.; (2) tungsten, 7·8 per cent.; carbon, 2·2 per cent. with hydrochloric acid.

In low carbon steels, and, indeed, possibly in fairly high carbon steels in the normal condition, the tungsten most probably exists as an iron-tungsten compound.

Thus Carnot and Goutal (*loc. cit.*), examining steels with carbon 0·4 to 0·6 per cent., tungsten 6·0 per cent., separated

\* R. A. Hadfield, "Alloys of Iron and Tungsten," *Journal of the Iron and Steel Institute*, 1903, No. II. p. 59.

† *Revue de Metallurgie*, May 1904,

‡ *Comptes Rendus*, vol. cxxv. p. 221.

a compound  $\text{Fe}_3\text{W}$  by treatment with dilute hydrochloric acid. An interesting corroboration of the existence of such a compound was described in the earlier paper by the author. A large number of iron-tungsten compounds have been recorded, including  $\text{FeW}_7$ ,\*  $\text{Fe}_3\text{W}_2$ .† According to Guillet, Behrens found  $\text{Fe}_2\text{W}$  in ferro-tungstens;  $\text{Fe}_4\text{W}$ ,  $\text{Fe}_5\text{W}$ , and  $\text{Fe}_6\text{W}$  have also been described by other workers.

Professor Turner, discussing Hadfield's paper (*loc. cit.*), pointed out a similarity between tungsten and silicon, which, with low percentages, existed as silicide dissolved in the iron, producing a uniform matrix; with higher proportions definite silicides were to be separated; whilst in the electric furnace silicide of carbon was obtained. Mr. C. A. Edwards, in his admirable Carnegie Report,‡ considers tungsten to exist in a state of solid solution in the iron below about  $1200^\circ \text{C}$ .; whilst the carbon is as  $\text{Fe}_3\text{C}$ , entering into solution as such at about  $770^\circ \text{C}$ . The tungsten forms a carbide of tungsten at about  $1200^\circ$ , which is responsible for the lowering of the recalescence-point temperature.

Professor Carpenter,§ speaking of high-speed tool steels, said: "It seems probable that the unhardened tool contains carbide of iron just like the carbon tool." Referring to the "completely new change between  $540^\circ \text{C}$ . and  $460^\circ \text{C}$ ." when cooled from  $1100^\circ \text{C}$ ., he said: "It is probable that the latter corresponds to the separation of a special carbide containing iron, and either tungsten, or manganese, or both, which gives the special self-hardening property to the self-hard tool."

Considering now the tungsten steels, many observations tend to support the view that the tungsten is not chemically associated with the carbon in normal 3 per cent. tungsten steels. For example, the eutectic ratio is practically unaltered. The Ar1 point is not affected in the tungsten steels in the manner usually experienced where double carbides are known to exist, such as manganese or nickel. Carpenter has shown that chromium does not affect the cooling curves at all in the

\* Poleck and Grützner, *Abstract of the Bulletin de Société Chimie*, 1893, No. VIII.

† E. M. Vigoroux, *Chemical News*, September 1906.

‡ *Journal of the Iron and Steel Institute*, 1908, No. II. p. 130.

§ Lecture before the Manchester Association of Engineers, November 28, 1908.



manner in which tungsten does. The only proof is the separation by Carnot and Goutal of  $\text{Fe}_3\text{C.WC}$ , and this from steels containing over 2.0 per cent. carbon.

Moreover, assuming this formula, 3.0 per cent. tungsten would only affect 0.54 per cent. carbon; hence, a change in characteristics would be expected beyond this carbon content. Such a change was not observed.

The evidence therefore supports the view that the tungsten will exist in the normal 3 per cent. tungsten steels, in the form of a tungstide of iron, probably  $\text{Fe}_3\text{W}$ .

The question as to whether the tungstide exists in the normal 3 per cent. steels, dissolved in a state of solid solution, or whether it exists as an isolated constituent in the mass of iron, is not easy to decide.

It would be expected that if a definite compound does exist as a separate constituent, then the microscope should reveal its presence. It must be admitted that no sign of such a constituent has been detected in these steels after a very exhaustive examination. This would support the view that the tungsten exists dissolved in the mass in some form. However, the fact that  $\text{Fe}_3\text{W}$  has been separated from a 6 per cent. tungsten steel clashes somewhat with this view.

Again, on comparing the resistivity values, further doubt is cast on the solution view. From Table VII. it will be seen that figures calculated according to Benedicks' formula—

$$\sigma = 7.6 + 26.8 \Sigma C \text{ where } \Sigma C = \text{sum of carbon equivalents in solution—}$$

for carbon steels (assuming Benedicks' discrepancy, which equalled 0.27 per cent. carbon dissolved in annealed steels above 0.50 per cent. total carbon, to be valid here), the observed results are actually in favour of the view that the tungsten is separated in these bars. The results are not so definite as could be wished owing to the comparatively small influence which tungsten exerts upon the resistivity even when in solution.

The treatments were as follows:—

“Annealed.”—Heated for three hours at about  $950^\circ \text{C}$ ., and slowly cooled.

"Normalised."—Heated for fifteen minutes at about 950° C., and cooled freely in air.

"Hardened."—Heated to 900° uniformly, and quenched at temperatures from 810° for the mildest, to 740° for the hardest specimen. The treatment was performed in the Brayshaw salt bath furnace.

The theoretical values below 0·5 per cent. carbon are not quite so definite as those above, and so are set in brackets. The results, at any rate beyond steel 921, are strongly in favour of the "separated" tungsten view, both in the annealed and hardened condition. The lower carbon steel values are rather higher than the calculated, but it must be remembered that in each of these three states these steels have been heated to very nearly their "lowering temperature," and possibly were not cooled slowly enough through the "low point" temperature range for the tungsten to completely separate. Steel 924, A and N specimens, are interesting in this direction.

The next table, Table VIII., shows the results published by Hadfield in 1903. The author has taken the liberty to add

TABLE VIII.—*Electrical Resistance of Hadfield's Steels (Annealed Condition).*

Marks.	Composition.				Specific Resistance.		
					Calculated.		Observed Values.
					For Tungsten not in Solution.	For Tungsten in Solution.	
	C.	W.	Si.	Mn.			
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
1294F	0·22	1·20	0·05	0·18	13·7	15·8	15·1
1294H	0·28	3·40	0·06	0·28	15·4	21·4	18·0
1294I	0·38	7·47	0·11	0·20	15·9	28·9	19·2
1294L	0·76	15·65	0·19	0·28	20·7	48·0	26·6

calculated values, according to Benedicks' law. The results

apparently confirm the author's figures, especially since the annealing temperature would most probably exceed the "lowering temperature," at any rate in the first two cases, and the cooling through the low point range, possibly not very slow.

The results obtained by H. Le Chatelier \* also support this view. Remarking upon the small influence of tungsten on the resistance, he says: "One is led to think that they (tungsten, molybdenum, and chromium) are isolated in the mass of the metal, in the form of definite compounds;" and further: "This view confirms that previously arrived at by Carnot in his chemical studies of similar steels."

Hence, although the resistance values can hardly be taken as positive proof as yet, the view that the tungsten may exist in some form, separated in the mass, is not without considerable support.

*The Transformations occurring during Heating and Cooling.*—Considering the reactions which take place on heating, and which are eventually responsible for the lowering of the recalescence point, the following introductory notes may be briefly considered:—

Osmond † noted the lowering effect produced by tungsten, and concluded that the carbon change was made to take place at a lower temperature. The tungsten prevented cementite from separating on cooling, and the high initial temperature necessary for lowering was to ensure the solution of the carbide.

Böhler, in his thesis on "Wolfram und Rapid Stahl," 1903, was of the opinion that both the normal and the lowered point correspond to the formation of pearlite.

Carpenter ‡ supported Osmond's view, stating that the rate of cooling was of importance to the position of the recalescence temperature. Thus, on p. 465: "It is thus quite possible that in all these alloys the critical range would be completed at the same temperature on cooling, whatever the initial temperature, provided the rate of cooling was sufficiently

\* *Contribution de l'Etude des Alliages*, p. 418.

† *Journal of the Iron and Steel Institute*, 1890, No. I. p. 61; *Revue de Métallurgie*, 1904, p. 348.

‡ *Journal of the Iron and Steel Institute*, 1905, No. I. p. 433.

slow." The view is supported by a set of experiments on a tungsten-chromium high-speed steel. Thus the tungsten will act "as a drag on changes which would take place in its absence, and prevents equilibrium at any given temperature from being quickly reached."

In a paper by the author\* on 3 per cent. tungsten steels only, it was found that rate of cooling was without influence on the position of the lowered recalescence; and, moreover, since the "lowering temperature" was proved to be quite a definite point, the view of tungsten acting merely "as a drag" was questioned. The view was advanced that at Ac1 the ordinary carbon change occurred on heating; and, at the lowering temperature, a further change occurred in which the tungsten was involved. The low recalescence corresponded to the reverse of the combined effect of these two changes.

Mr. C. A. Edwards (*loc. cit.*) supports the author's work, that the low recalescence temperature is not a function of carbon content, as stated by Osmond. He also notes that beyond 6.0 per cent. of tungsten the low point appears fairly constant about 380° C.

Mr. Edwards advances the view that the low point is not the "carbide of iron change" depressed by tungsten, the reason being that on again heating to, say, 900° C., time is necessary for the recovery of a clean normal Ar1 point. He concludes: "Accordingly, the writer is of the opinion that the low point is not Ar1 lowered by tungsten, but that a carbide of tungsten is slowly formed at 1200° C., which has a critical temperature quite independent of Ar1."

In Professor Carpenter's paper referred to above, it will be seen that the view of tungsten acting merely "as a drag" has been abandoned in favour of the view that the low point is a "completely new change." An important difference between Dr. Carpenter and Mr. Edwards is, however, that the former attributes the low point in tungsten steels to "a special carbide containing iron, and either tungsten or manganese, or both"; the latter speaks exclusively of "carbide of tungsten."

In considering the above hypotheses, it is seen that three

\* *Journal of the Iron and Steel Institute*, 1907, No. I. p. 291.

distinct views are expressed as to what is the cause of the low recalescence, thus:—

1. The low point marks the separation of ordinary cementite,  $\text{Fe}_3\text{C}$ .
2. At the low point a special double or triple carbide separates.
3. The low point is due to an entirely new carbide of tungsten, which is deposited at that temperature.

*Consideration of the Hypotheses advanced.*—Taking the last hypothesis first. The argument by Mr. Edwards leading to this is based on the fact that time is necessary for recovery of the normal point after lowering has taken place—the carbide of tungsten being gradually transformed into carbide of iron by soaking below the lowering temperature. This is undoubtedly a feasible explanation of the necessity for soaking which certainly exists. The necessity for soaking may possibly be explained by other means, however, and certain other experimental facts are very difficult to reconcile with this hypothesis.

Thus, in the first case, a tungsten steel slowly cooled from  $1200^\circ$ , and exhibiting only the low recalescence, should have the whole of its carbon as carbide of tungsten. Specimens of the F series herein described, cooled slowly from over  $1200^\circ$  and quenched below  $500^\circ$ , are, so far as can be seen, perfect specimens of carbon steel structures, and do not suggest a special carbide (see Figs. 20, 21, 22, Plate XIII.).

It would be expected also that if, on cooling from  $1200^\circ$ , the piece was kept for, say, two hours about  $900^\circ$ , the carbide of tungsten would be decomposed (just as is supposed when reheated to this temperature), and a normal recalescence shown. Such is found not to be the case with these 3 per cent. tungsten steels.

Again, it would be expected that by keeping tungsten content constant, and increasing carbon in a series, some point would be reached where the carbon exceeded the equivalent necessary for tungsten carbide, in which case a normal Ar1 would also be expected, due to the excess cementite. This has not been found, and in the author's series, for example, 3 per cent. tungsten and 1.24 per cent. carbon would represent, assuming all tungsten in combination, a formula  $\text{WC}_{6.3}$ , which appears improbable.

Then again, if a definite carbide of tungsten is formed and is responsible for the low point, the temperature of the latter should be practically uninfluenced by the tungsten content, say, 1 per cent. up to 5 or 6 per cent. Only its magnitude should be affected. It is well known, however, that the depression of the point is dependent on the tungsten content.

It was found, in studying the cooling curves, that steels cooled from about  $1200^{\circ}$ , and giving a clean low point, showed a low point of distinct maximum intensity with carbon content 0.9 per cent. This was, moreover, confirmed when free cementite was found in specimens cooled from above  $1200^{\circ}$  and quenched above the low point.

Again, except for the fact that a free Ar2 point (*i.e.* in mild steel) is not lowered, the shape of the curve on cooling from  $1200^{\circ}$  strongly resembles the normal curve. For example, in a 0.5 per cent. carbon steel (3 per cent. tungsten) the Ar3.2 point is lowered to a position relatively very similar to the lowered Ar1, as the normal Ar3.2 holds to the normal Ar1. The low point temperature, whilst independent of carbon content, is almost certainly dependent on tungsten content, at least in carbon-tungsten steels up to, say, 6.0 per cent. tungsten.

The above facts are very difficult to reconcile with the view that a carbide of tungsten is formed. Even hypothesis 2, assuming a double carbide of iron and tungsten to be formed, the above facts are difficult to understand. A modification of this second hypothesis, by which a double carbide formed at the lowering temperature, decomposes at the low recalescence into  $\text{Fe}_3\text{C}$  and tungstide of iron, has some advantages. However, the low point maximum at 0.9 per cent. carbon, the lowering of the Ar3.2 point, and other evidence, renders the acceptance of this view very difficult.

The only satisfactory explanation of the several facts detailed above, together with the general facts obtained by an extensive study of the 3 per cent. tungsten steels, is that the actual change at the low temperature is really a separation of cementite by decomposition of martensite. The similarity in form of the cooling curve from  $1200^{\circ}$  to the curve from  $900^{\circ}$ , the maximum intensity of the low point at 0.9 per cent. carbon,

the general evidence of microstructures, all tend to the view that the tungsten does not form a compound with the carbon. The influence of the tungsten is, however, quite definite, pointing to a definite change at the lowering temperature, which form holds until the low temperature point is reached. What, then, can be the change which holds the carbon in the dissolved state down to this low point?

As a tentative explanation, suppose the  $\text{Fe}_3\text{W}$  were to exist separated in the mass in the normal steel (as previous facts showed not unlikely). Then, at the lowering temperature, this goes into solution, and in this new solution the  $\text{Fe}_3\text{C}$  is dissolved. The  $\text{Fe}_3\text{W}$  does not separate again until the low point is reached, and then the  $\text{Fe}_3\text{C}$  immediately follows.

This would explain a definite "lowering point" and "low recalescence," and that cooling from  $900^\circ$ , after previously cooling from  $1200^\circ$ , gives a normal curve. It will be seen that if this hypothesis is correct there should be an increase in resistivity beyond the lowering temperature, due to the increase in dissolved impurity. It was decided to test this by determining the resistivity of specimens quenched at suitable temperatures, and the results will be briefly given.

*Resistivity of Heat-treated Specimens.*—Specimens 6 centimetres long, 0.8 centimetre diameter, were heated in an electric tube furnace, with a carefully standardised thermocouple in contact. An unsaturated steel (No. 920—carbon, 0.57 per cent.; tungsten, 3.17 per cent.), and a supersaturated steel (No. 719—carbon, 1.24 per cent.; tungsten, 3.02 per cent.) may be reported upon. The treatments were as follows:—

1. Heated to  $950^\circ\text{C}$ . for 1 hour, and quenched in water.
2. Heated to  $1200^\circ\text{C}$ . for 25 minutes, and quenched in water.
3. Heated to  $1200^\circ$  to  $1230^\circ\text{C}$ . for 45 minutes, cooled to  $630^\circ$  in 1 hour 28 minutes, and quenched in water.

*Sections etched in Meta-nitrobenzolsulphonic Acid in Alcohol.\**—Steel 920 showed structures confirming those already described, and it was noted that there was little if any free

\* The experiments were carried out in Dr. Benedicks' laboratory, Upsala, and it was upon his advice that the new etching medium was tried. It was found of considerable help by Dr. Benedicks in etching martensite-austenite specimens.

## PLATE X



FIG. 1.—Steel 965. Cast. Magnified 150 diameters.

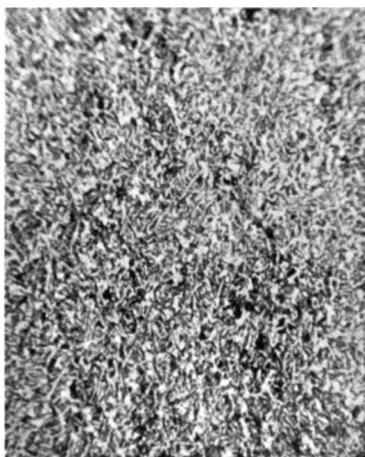


FIG. 2.—Steel 920. Rolled. Magnified 150 diameters.

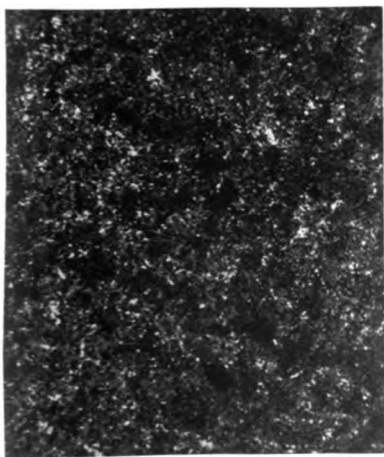


FIG. 3.—Steel 965. Rolled. Magnified 150 diameters.

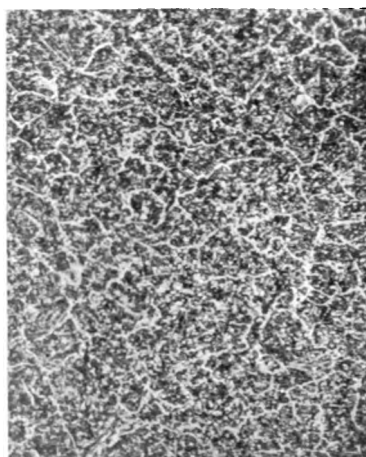


FIG. 4.—Steel 719. Rolled. Magnified 150 diameters.

*Slightly reduced in reproduction.*





# PLATE XI

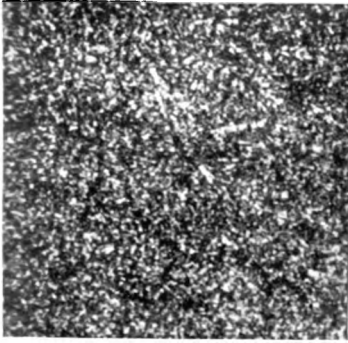


FIG. 5.—Steel 920. Carbon, 0.57 per cent.; tungsten, 3.17 per cent. Heated to 950°; quenched at 950°. Magnified 300 diameters.

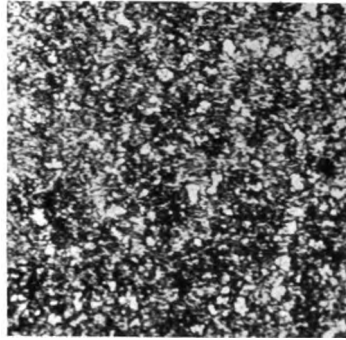


FIG. 6.—Steel 920. Carbon, 0.57 per cent.; tungsten, 3.17 per cent. Heated to 950°; quenched at 740°. Magnified 300 diameters.

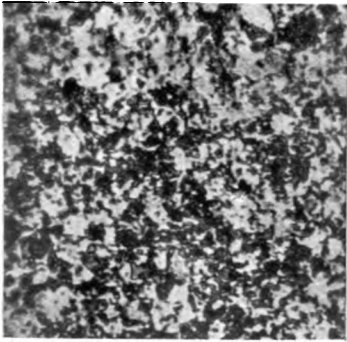


FIG. 7.—Steel 920. Carbon, 0.57 per cent.; tungsten, 3.17 per cent. Heated to 950°; quenched at 620°. Magnified 300 diameters.

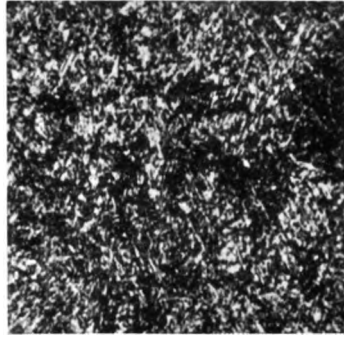


FIG. 8.—Steel 920. Carbon, 0.57 per cent.; tungsten, 3.17 per cent. Heated to 1235°; quenched at 1235°. Magnified 300 diameters.

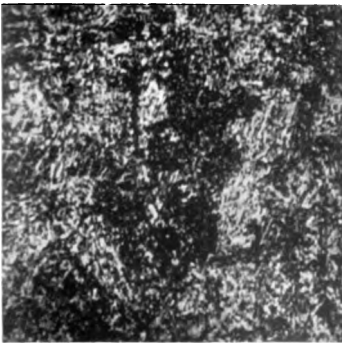


FIG. 9.—Steel 920. Carbon, 0.57 per cent.; tungsten, 3.17 per cent. Heated to 1220°; quenched at 630°. Magnified 300 diameters.

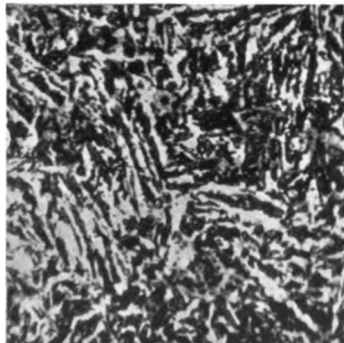


FIG. 10.—Steel 920. Carbon, 0.57 per cent.; tungsten, 3.17 per cent. Heated to 1210°; quenched at 480°. Magnified 300 diameters.

*Slightly reduced in reproduction.*



## PLATE XII

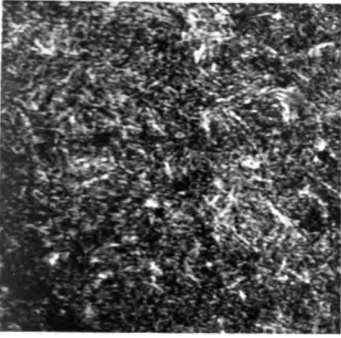


FIG. 11.—Steel 965. Carbon, 0·89 per cent. ; tungsten, 3·08 per cent. Heated to 1000°; quenched at 1000°. Magnified 300 diameters.

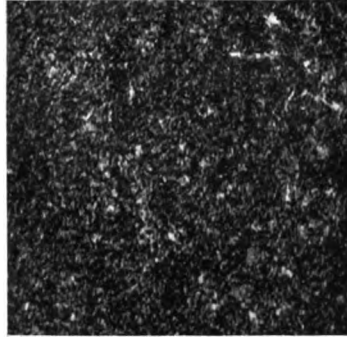


FIG. 12.—Steel 965. Carbon, 0·89 per cent. ; tungsten, 3·08 per cent. Heated to 980°; quenched at 740°. Magnified 300 diameters.

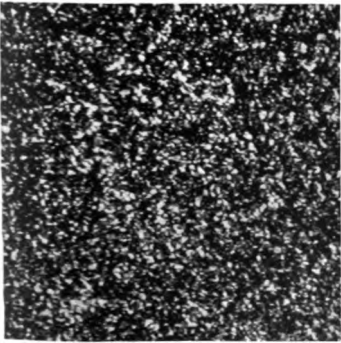


FIG. 13.—Steel 965. Carbon, 0·89 per cent. ; tungsten, 3·08 per cent. Heated to 980°; quenched at 615°. Magnified 300 diameters.

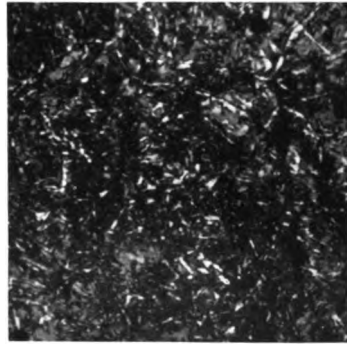


FIG. 14.—Steel 965. Carbon, 0·89 per cent. ; tungsten, 3·08 per cent. Heated to 1260°; quenched at 1260°. Magnified 300 diameters.

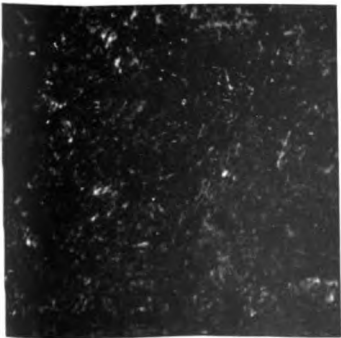


FIG. 15.—Steel 965. Carbon, 0·89 per cent. ; tungsten, 3·08 per cent. Heated to 1220°; quenched at 650°. Magnified 300 diameters.

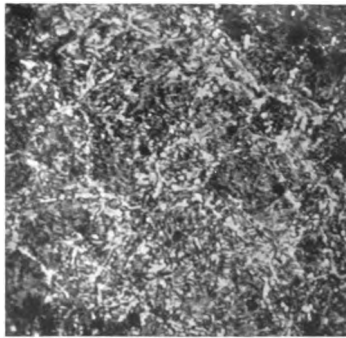


FIG. 16.—Steel 965. Carbon, 0·89 per cent. ; tungsten, 3·08 per cent. Heated to 1230°; quenched at 487°. Magnified 300 diameters.

*Slightly reduced in reproduction.*



# PLATE XIII



FIG. 17.—Steel 719. Carbon, 1·24 per cent. ; tungsten, 3·02 per cent. Heated to 1000°; quenched at 1000°. Magnified 300 diameters.

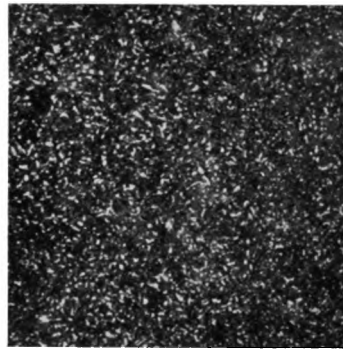


FIG. 18.—Steel 719. Carbon, 1·24 per cent. ; tungsten, 3·02 per cent. Heated to 1000°; quenched at 745°. Magnified 300 diameters.

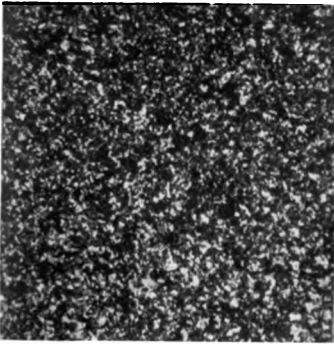


FIG. 19.—Steel 719. Carbon, 1·24 per cent. ; tungsten, 3·02 per cent. Heated to 980°; quenched at 620°. Magnified 150 diameters.

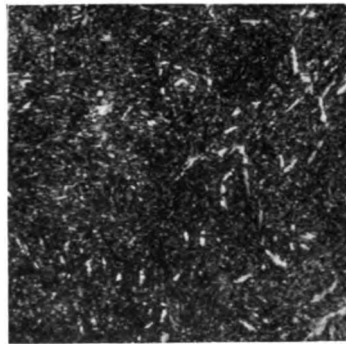


FIG. 20.—Steel 719. Carbon, 1·24 per cent. ; tungsten, 3·02 per cent. Heated to 1260°; quenched at 1260°. Magnified 300 diameters.



FIG. 21.—Steel 719. Carbon, 1·24 per cent. ; tungsten, 3·02 per cent. Heated to 1245°; quenched at 645°. Magnified 300 diameters.



FIG. 22.—Steel 719. Carbon, 1·24 per cent. ; tungsten, 3·02 per cent. Heated to 1250°; quenched at 480°. Magnified 300 diameters.

*Slightly reduced in reproduction.*



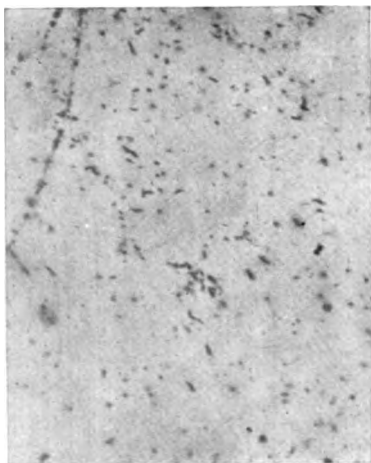


FIG. 23.—Steel 719. Carbon, 1.24 per cent. ; tungsten, 3.02 per cent. Heated to 1245°; quenched at 645°; etched in hydrochloric acid in alcohol. Magnified 300 diameters.

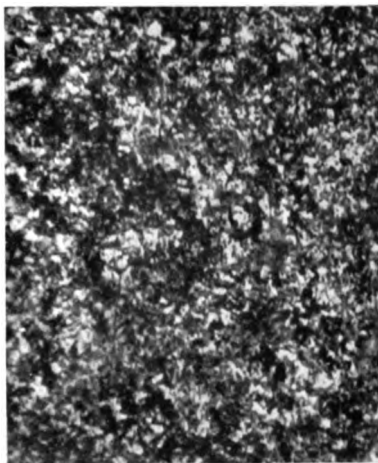


FIG. 24.—Steel 719. Carbon, 1.24 per cent. ; tungsten, 3.02 per cent. Heated to 980°; quenched at 620°; etched in hydrochloric acid in alcohol. Magnified 300 diameters.

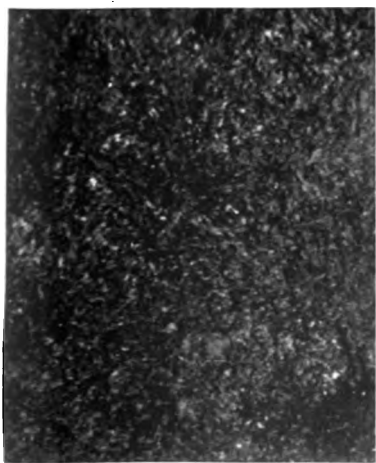


FIG. 25.—Steel 719. Carbon, 1.24 per cent. ; tungsten, 3.02 per cent. Heated to 1000°; quenched at 1000°; etched in iodine. Magnified 300 diameters.



FIG. 26.—Steel 719. Carbon, 1.24 per cent. ; tungsten, 3.02 per cent. Heated to 1260°; quenched at 1260°; etched in iodine. Magnified 300 diameters.

*Slightly reduced in reproduction.*





## PLATE XV

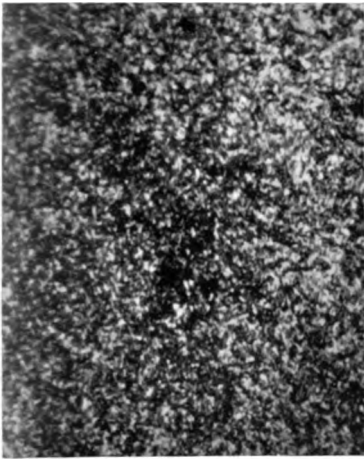


FIG. 27.—Steel 920. Carbon, 0.57 per cent. ; tungsten, 3.17 per cent. Air cooled from 850°. Magnified 150 diameters.

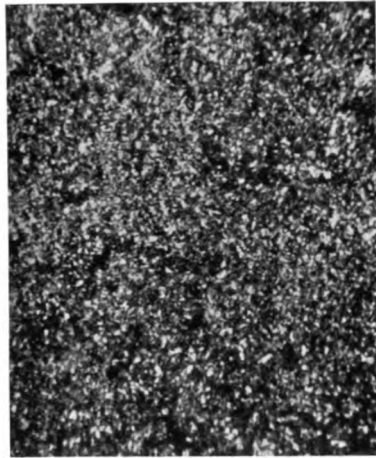


FIG. 28.—Steel 920. Carbon, 0.57 per cent. ; tungsten, 3.17 per cent. Air cooled from 990°. Magnified 150 diameters.



FIG. 29.—Steel 920. Carbon, 0.57 per cent. ; tungsten, 3.17 per cent. Air cooled from 1110°. Magnified 150 diameters.



FIG. 30.—Steel 920. Carbon, 0.57 per cent. ; tungsten, 3.17 per cent. Air cooled from 1250°. Magnified 150 diameters.

*Slightly reduced in reproduction.*



## PLATE XVI

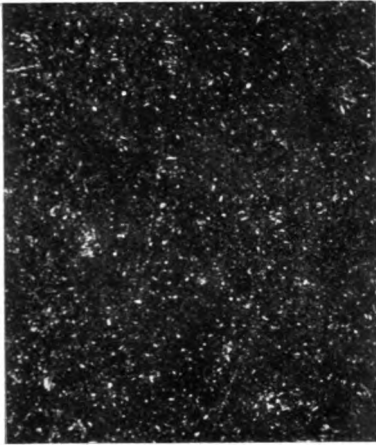


FIG. 31.—Steel 965. Carbon, 0.89 per cent. ; tungsten, 3.08 per cent. Air cooled from 850°. Magnified 150 diameters.

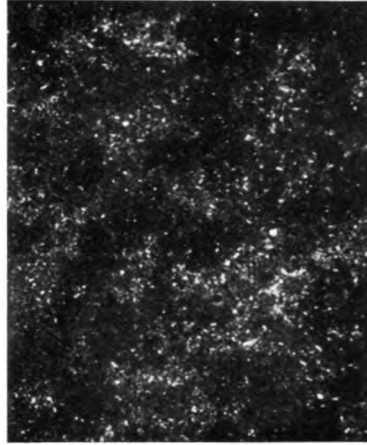


FIG. 32.—Steel 965. Carbon, 0.89 per cent. ; tungsten, 3.08 per cent. Air cooled from 990°. Magnified 150 diameters.



FIG. 33.—Steel 965. Carbon, 0.89 per cent. ; tungsten, 3.08 per cent. Air cooled from 1110°. Magnified 150 diameters.

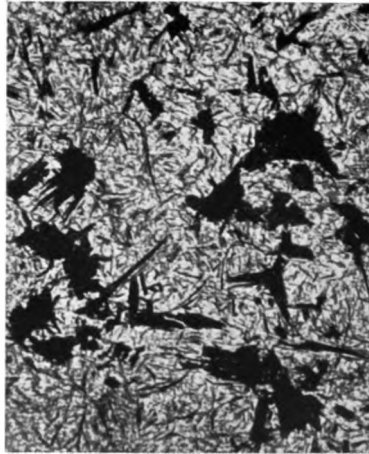


FIG. 34.—Steel 965. Carbon, 0.89 per cent. ; tungsten, 3.08 per cent. Air cooled from 1250°. Magnified 150 diameters.

*Slightly reduced in reproduction.*



# PLATE XVII

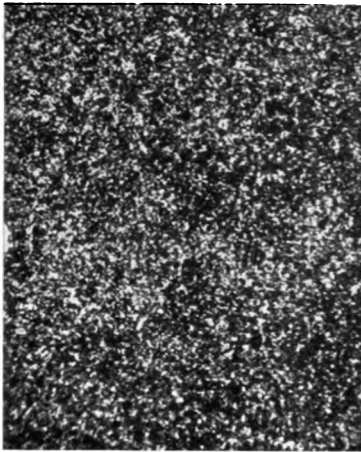


FIG. 35.—Steel 719. Carbon, 1.24 per cent. ; tungsten, 3.02 per cent. Air cooled from 850°. Magnified 150 diameters.

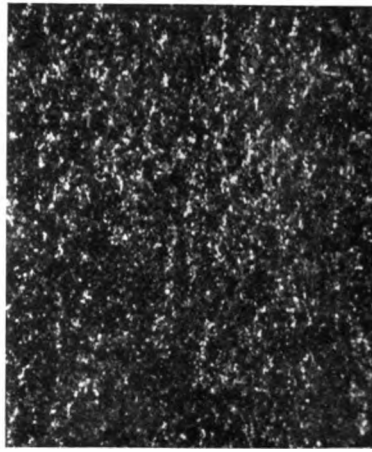


FIG. 36.—Steel 719. Carbon, 1.24 per cent. ; tungsten, 3.02 per cent. Air cooled from 990°. Magnified 150 diameters.

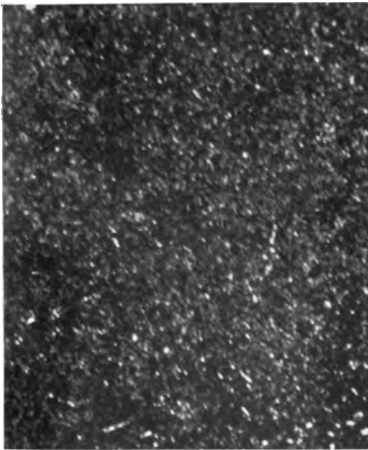


FIG. 37.—Steel 719. Carbon, 1.24 per cent. ; tungsten, 3.02 per cent. Air cooled from 1110°. Magnified 150 diameters.

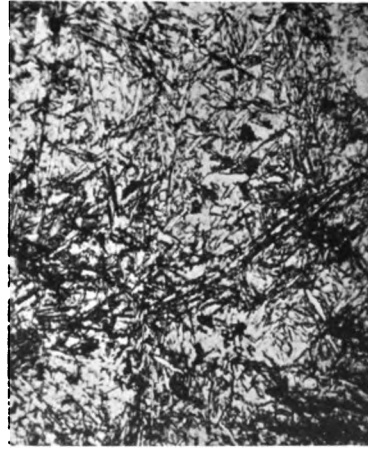


FIG. 38.—Steel 719. Carbon, 1.24 per cent. ; tungsten, 3.02 per cent. Air cooled from 1250°. Magnified 150 diameters.

*Slightly reduced in reproduction.*



ferrite in Section III. For some reason 719 I. is not hardened, showing a profusion of troostite. 719 II. shows some signs of austenite in fine triangles; whilst 719 III. shows generous lines of free cementite, long and straggly as before, with occasionally a peculiar herring-bone structure.

The resistivities were as follows in Table IX. :—

TABLE IX.

Specimen.	Microhms per Cubic Centimetre. Resistivity.	Remarks.
920 I.	25.6	Calculated value for all carbon, no tungsten in solution, $\sigma = 25.05$ .
II.	28.9	Calculated value for all carbon, all tungsten in solution, $\sigma = 30.55$ .
III.	27.0	...
719 I.	31.4	Shows troostite; hence resistivity low.
II.	42.6	Calculated value, all carbon and tungsten in solution, $= 48.3$ .
III.	37.4	Shows free cementite. Calculated all tungsten and 0.9 per cent. carbon in solution, $\sigma = 38.4$ .

The differences are small, but there is a tendency towards increase in II. The 719 set are disappointing from resistivity standpoint.

A few typical results by other workers may be included. Table X. gives two typical examples, one carbon and one tungsten steel, by Dr. L. Holborn.\*

TABLE X.

No.	Analysis of Steel.				Hardening Temperature.	Specific Electrical Resistance.
	C.	W.	Si.	Mn.		
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Degrees C.	
I.	0.54	2.70	0.22	0.31	765	31.7
	...	...	...	...	920	31.1
	...	...	...	...	1050	34.0
	...	...	...	...	...	...
II.	0.81	nil	0.29	0.28	855	31.7
	...	...	...	...	910	32.3
	...	...	...	...	1090	30.6
	...	...	...	...	...	...

\* *Zeitschrift für Instrumentenkunde*, 1891, vol. xi. pp. 118-124.



It is interesting to note that steel I., quenched at  $1050^{\circ}$  (which would exceed the lowering temperature), shows an increase in resistivity. The slight decrease in resistivity for the carbon steel is difficult to explain.

H. Le Chatelier \* also provides some interesting data, and typical results are included in Table XI.

TABLE XI.†

No.	Analysis.				Quenching Temperature.	Resistivity.	Calculated Resistivity.
	C.	W.	Si.	Mn.			
I.	Per Cent. 0.6	Per Cent. 5.0	Per Cent. 0.2	Per Cent. 0.3	760	21.0	{ Probably not fully hardened
	...	...	...	...	800	29.4	
	...	...	...	...	850	31.5	
	...	...	...	...	1100	37.8	
II.	0.55	2.9	0.2	0.4	750	21.7	...
	...	...	...	...	800	25.2	
	...	...	...	...	1100	32.5	
III.	0.76	2.7	0.3	0.44	730	25.9	...
	...	...	...	...	780	29.6	
	...	...	...	...	850	31.5	
	...	...	...	...	1100	35.2	

The author would point out that all the steels are unsaturated, so that gradual solution of excess cementite does not come into play.

In order to bring the point forward independent of the general analysis of the steel, below is given the increment in resistivity due to an increase in quenching temperature  $850^{\circ}$  to  $1100^{\circ}$ .

Steel No. . . . .	I.	II.	III.
Increase in resistivity in microhms per cubic centimetre - $850^{\circ}$ to $1100^{\circ}$ . }	6.3	4.2	4.7
Calculated increase due to solution of tungsten . . . . . }	8.7	5.2	4.7

\* *Contribution de l'Etude des Alliages*, p. 418, *et seq.*

† The data are actually reported in the form  $\frac{\text{resistance after quenching}}{\text{resistance before quenching}}$ , and the above figures are worked out accordingly.

A carbon steel—carbon, 0·84 per cent.—gave the following figures:—

Quenching Temperature. Degrees C.	Resistivity. Microhms per Cubic Centimetre.
710	16·0
740	20·8
810	33·6
850	35·2
1000	35·2

Quenching at 740° has partly hardened. Note no increase beyond 850°.

The general increase in resistivity in tungsten steels on quenching beyond the lowering temperature is very interesting, and lends colour to the view previously expressed, that the "lowering temperature" marks the point of solution of a tungsten compound.

In conclusion, the author would state that the latter hypothesis is advanced in no dogmatic spirit. The revolutionary nature of the hypothesis is perfectly well realised, but the author cannot but believe that the experimental facts justify its consideration. The heat-treatment experiments and photomicrographs have been performed at the Sheffield University, and the author would here tender his hearty thanks to Professor J. O. Arnold, D.Met., and his staff, for the practical facilities so generously afforded. To Dr. Carl Benedicks, Upsala, the author's grateful thanks are due, not only for the splendid apparatus placed at his disposal for resistivity determinations and general work, but also for much kindly counsel on the former subject.

This being the final report as an 1851 Royal Exhibition Scholar, the author would beg to record his hearty appreciation of the Commissioners' award, which enabled him to carry out these researches.

#### SUMMARY.

Reviewing the paper, the following observations may be made:—

Hardness tests and exhaustive microscopic examination support in every respect the conclusions previously recorded

upon the cooling-curve work. First, that the "lowering temperature" marks a definite reaction in which the tungsten is involved; and, secondly, that the rate of cooling from above the lowering temperature is without influence on the low point. Some facts are stated and observations made, suggesting that the hypothesis of Edwards, that the lowering of the point is due to the formation of a carbide tungsten, is untenable.

The theory of a double carbide formation is also difficult to reconcile with cooling-curve and microscopic facts. A tentative hypothesis is given, wherein the lowering of the recalescence point is attributed to the solution of a tungsten compound, probably  $\text{Fe}_3\text{W}$ , at the lowering temperature. The tungstide is reprecipitated at the low point, and the  $\text{Fe}_3\text{C}$  immediately separates also.

Some figures in support of the latter view are included.

## CORRESPONDENCE.

Professor CARPENTER and Mr. EDWARDS wrote that the Institute was indebted to Mr. Swinden for his paper on the "Constitution of Carbon-tungsten Steels," and his attempt to throw more light on this complicated subject. They thought that in that discussion a distinction should be drawn between carbon-tungsten steels on the one hand, and high-speed tool steels (carbon-tungsten chromium steels) on the other hand. In a previous paper by one of them\* it was shown that not only the initial temperature, but also the rate of cooling, influenced the inversion temperature or temperatures of a high-speed tool steel, whereas Mr. Swinden found that, in a carbon-tungsten steel containing 3 per cent. of tungsten, "the rate of cooling was without influence on the position of the lowered recalescence."† In their opinion that did not constitute a discrepancy between two sets of experimental results which had to be explained, but indicated a difference in properties between the two kinds of steels.

Mr. Swinden, in considering the hypotheses which had been put forward to explain the low "recalescence," gave the following summary, p. 246 :—

- "1. The low point marks the separation of ordinary cementite  $\text{Fe}_3\text{C}$ .
- "2. At the low point a special double or triple carbide separates.
- "3. The low point is due to an entirely new carbide of tungsten which is deposited at that temperature."

It appeared to the writers that there was agreement between him and them, that at temperatures between  $1000^\circ$  and  $1100^\circ \text{C}$ . a reaction took place in which iron, carbon, and tungsten were involved. Such differences of opinion as existed at present centred round the nature of the compound or compounds that separated on cooling from those temperatures. Mr. Swinden, after advancing certain objections to Nos. 2 and 3, concluded that No. 3 was "untenable" (p. 252), and No. 2 "difficult to reconcile with cooling curve and microscopic facts." With those objections they were not concerned for the moment, though some of them applied equally strongly to Mr. Swinden's own hypothesis No. 1. They merely wished to state that the present methods of chemical analysis did not help them to decide whether No. 2 or No. 3 was the more probable view, and that it was rather a misuse of terms to say that an "important difference" existed between the two explanations. It was simply a question whether the carbide of tungsten separated with or without iron or manganese.

Mr. Swinden's hypothesis was as follows :—At the lowering temperature an iron-tungstide, such as  $\text{Fe}_3\text{W}$ , went into solution, which then dissolved iron carbide. On cooling the iron-tungstide separated at the low recalescence temperature, and then the iron carbide "immediately follows."

\* *Journal of the Iron and Steel Institute*, 1906, No. I. p. 466.

† *Ibid.*, 1907, No. I. p. 291.

(1) If that hypothesis were correct, two chemical compounds, iron-tungstide and iron-carbide should exist in carbon-tungsten steels cooled from such a temperature, and should be detected by the microscope. With regard to the iron-tungstide, Mr. Swinden said (p. 242): "It must be admitted that no sign of such a constituent has been detected in these steels after a very exhaustive examination." That statement was borne out by the writers' experience. An alloy containing 19.0 per cent. of tungsten and 0.60 per cent. of carbon, in the annealed condition, showed no special structural constituent, indicating that those steels did not contain the compound  $\text{Fe}_3\text{W}$ , as a separate constituent. That was a difficulty in the way of accepting Mr. Swinden's hypothesis.

(2) Judging from the properties of ferro-tungstens which approximated in composition to the compound  $\text{Fe}_3\text{W}$ , it seemed most probable that that, like other intermetallic compounds, was hard and more or less brittle. That consideration had an important bearing on Mr. Swinden's hypothesis, because if the compound were hard, the hardness of annealed tungsten steels should increase with the amount of  $\text{Fe}_3\text{W}$  present. Against that it must be stated that an alloy containing 19.0 per cent. of tungsten and 0.60 per cent. of carbon was no harder than a 0.60 per cent. carbon steel.

(3) If Mr. Swinden's hypothesis was correct, a pure iron-tungsten alloy containing no carbon should, on cooling from  $1250^\circ \text{C.}$ , show the low recalcence. That would afford a direct experimental test, and if Mr. Swinden had not already carried it out, the writers would suggest that he should do so.

Mr. R. MATHER (Middlesbrough) wrote that Mr. Swinden should be heartily congratulated on having, by his very careful and exhaustive work, cleared up some of the perplexities in which the properties of carbon-tungsten steels were involved and on having advanced a feasible, although only tentative, explanation of those properties. He thought that the hypothesis would account more satisfactorily than any other for the observed facts; but while such positive evidence as bore on the hypothesis was in its favour, there were several gaps in the evidence which might reasonably have been expected to be available for its support. The validity of Mr. Swinden's suggestion depended on the existence in the steel under ordinary conditions of the tungsten in a structurally separate form, presumably as a tungstide,  $\text{Fe}_3\text{W}$  (although the composition was not of prime importance so long as it was carbon-free). Hence the failure to identify that compound, forming about 6 per cent. of the whole mass, under the microscope was disappointing. If, as was suggested, the previously free  $\text{Fe}_3\text{W}$  went into solution at the lowering temperature (and here it would have been the  $\text{Fe}_3\text{W}$  which would have dissolved at that temperature in an already-formed  $\text{Fe}_3\text{C}$  solution rather than conversely) there would surely have been some indication of it in the heating curves? It did not appear, however, that such a point had been observed. And similarly, if Mr. Swinden's hypothesis were correct, it might have been expected that the lowered recalcence point would be larger than the normal point, owing to the separation of  $\text{Fe}_3\text{W}$

in addition to the  $\text{Fe}_3\text{C}$ ; and further, a high tungsten steel should give a larger point than a low tungsten steel. On the former point, support was found in the curves published in the author's previous paper,\* where Plates XVII., XVIII., XIX., XX., XXI., and XXIV. all showed to a greater or less degree that the low point tended to be larger than the normal point, if the conditions of cooling were assumed to be practically the same throughout the investigations on any one steel. Moreover, those same cooling curves (see Plate XXIII.) showed that when the steel had been taken just to the lowering temperature but not sufficiently high, or perhaps not for a sufficient time thoroughly to have completed the solution of the  $\text{Fe}_3\text{W}$  which Mr. Swinden suggested took place there, two recalescence points occurred in cooling, one at approximately the normal point and the other at the "low point," each being smaller than either the proper normal point or the fully lowered point. The higher one, namely the  $\text{Fe}_3\text{C}$  point, decreased as the lowering temperature was more fully reached or maintained, and the lower one, which corresponded to an  $\text{Fe}_3\text{W}$  point, decreased in size with the lowering of the original temperature from which the steel was cooled. Thus those deductions from the cooling curves, although perhaps only of secondary value, further supported Mr. Swinden's interesting theory which, in spite of the defects in its proof, certainly held the field successfully against the views previously put forward on the subject.

Mr. T. SWINDEN, in reply, thanked Professor Carpenter and Mr. Edwards for their contribution to the discussion on his paper. They suggested in their first paragraph that chromium was responsible for the important difference in results obtained from the two respective series of experiments. It was, however, in Professor Carpenter's own paper,† summarising on iron-carbon-tungsten alloys, that the remarks on the "widening" or "dragging out of the lower limit" of the point, and the influence of rate of cooling, were introduced. The reader was referred, moreover, direct from that paragraph to "some further remarks" supplementing them, with further results, obtained that time from an ordinary English high-speed steel containing chromium. Professor Carpenter had evidently not realised the "two kinds of steels," so far as those points were concerned, and he (Mr. Swinden) had not read of any modification of the above views on carbon-iron-tungsten alloys by Dr. Carpenter. He could scarcely agree with Professor Carpenter and Mr. Edwards' view that it was a "misuse of terms" to say that an important difference existed between the theories of Dr. Carpenter and Mr. Edwards respectively. Surely it was of the greatest importance to know whether the  $\text{Fe}_3\text{C}$  was entirely decomposed, and whether the carbide was a "double carbide containing either iron or manganese, or both," or a carbide of tungsten. He fully recognised, as noted on p. 242 of the paper, that the inability to distinguish a separate constituent in the annealed steels was opposed to his view. In reference

\* *Journal of the Iron and Steel Institute*, 1907, No. I. p. 291.

† *Ibid.*, 1906, No. I. pp. 448-9.

to Professor Carpenter and Mr. Edwards' second paragraph, it could only be said that with the present state of knowledge of kinds of hardness and their measurement, the argument did not possess great weight. It was his intention to determine thermal data upon a pure iron-tungsten alloy as soon as possible. Professor Carpenter having now admitted that the influence of tungsten, at least in high-speed steels, was of a definite nature, and that a new recalcence was obtained by cooling from the high temperature and not merely the carbon point widened, the real point of difference between him (Mr. Swinden) and his critics was as to whether the tungsten was associated with the carbon in the form of a compound constituent precipitated at the low point. In face of the arguments advanced on pp. 246-247 of the paper, not one of which Professor Carpenter and Mr. Edwards had attempted to meet, he still adhered to the view that the tungsten was not associated with carbon in the manner suggested. Mr. Mather had evidently devoted much study to the paper, and his thoughtful contribution was to be welcomed. With regard to the point noted by Mr. Mather, and also by Professor Carpenter and Mr. Edwards, as to whether the  $\text{Fe}_3\text{C}$  or  $\text{Fe}_3\text{W}$  dissolved first, he (Mr. Swinden) had to apologise for the rather ambiguous reference he had made on p. 248 respecting the matter. It was not intended to imply that the  $\text{Fe}_3\text{C}$  was necessarily dissolved after the  $\text{Fe}_3\text{W}$ . As noted in his previous paper,\* and also several times in the present paper, the ordinary Acl point occurred, and the solution of excess cementite took place almost as for carbon steels, so far as temperature was concerned. The  $\text{Fe}_3\text{W}$  would therefore dissolve in an already formed solution of  $\text{Fe}_3\text{C}$ .

Up to the present no recalcence point had been observed at the lowering temperature, but there was no doubt that the lowered point was apparently larger than the ordinary Acl of a similar carbon steel. In further work upon which the author was engaged, it was hoped that more definite information would be obtained on those interesting and important phenomena.

\* *Loc. cit.*, p. 320.

## THE CORROSION OF IRON.

BY J. NEWTON FRIEND, PH.D., M.SC. (DARLINGTON).

It is well known that iron readily corrodes when exposed to the action of liquid water and air at ordinary temperatures. At first this was regarded as a simple case of oxidation, similar to that which obtains when iron is heated in air. We now know, however, that the reaction is more complex, and several theories have been suggested by way of explanation. Of these there are two only which merit consideration here, for the others have already been proved to be untenable.\* These are what are known as the acid and electrolytic theories respectively.

According to the former, as its name implies, pure water, oxygen, and iron may remain in contact with one another for an indefinite period without the formation of rust. The presence of a trace of some acid to act as catalyser is absolutely essential if oxidation of the metal is to begin. As carbonic acid is very prevalent in natural air and water, we may assume that, in all ordinary cases of rusting, it is this acid which acts as the catalyser, by attacking a portion of the iron, forming ferrous carbonate,  $\text{FeCO}_3$ , or perhaps the soluble ferrous hydrogen carbonate,  $\text{FeH}_2(\text{CO}_3)_2$ . This is then converted into rust by the oxygen of the air with the simultaneous liberation of carbon dioxide, which is now free to attack a fresh portion of the iron. We thus see that an infinitesimal amount of carbon dioxide in the presence of water and oxygen would be capable of converting an indefinite amount of iron into rust.

I may, perhaps, at this point be allowed to take exception to Dr. William H. Walker's recent statement† that I am a supporter of the so-called "carbonic acid theory of corrosion." This theory implies that carbonic acid is the only acid which

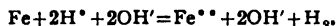
\* See Friend, *Journal of the Iron and Steel Institute*, 1908, No. II. p. 5.

† *Journal of the Iron and Steel Institute*, 1909, No. I. p. 69.



can or does effect the corrosion of iron, whereas it should be well known that any acid capable of attacking iron is also effective.\* In my previous paper, already referred to, carbonic acid was cited for the reason given above. It is to the general "acid theory of corrosion" that the results of numerous experiments compel me to adhere, and the importance of bearing this distinction in mind has already been emphasised by Dr. Gerald T. Moody in a letter to *Nature* of March 7, 1907.

According to the electrolytic theory of corrosion, on the other hand, the presence of an acid, even in traces, is not essential to the oxidation of the iron, liquid water and oxygen alone being necessary. It is assumed that pure water is ionised to a small but definite extent, and that when a strip of iron comes in contact with it, positively charged iron ions are sent out into the water. Hydrogen ions simultaneously leave the liquid, which latter now becomes virtually a solution of ferrous hydroxide in water. Thus:—



Addition of oxygen now causes the ferrous iron to assume the ferric condition, and rust appears.

It might appear at first sight that to decide between the two theories would be a matter of great simplicity, for the presence of an acid can readily be detected by means of certain reagents such as litmus and methyl orange. But further consideration shows that such is not the case. It has already been pointed out that, according to the acid theory, a single molecule of acid is sufficient to start the process of rusting, and certainly in practice, a very small number would be able to produce a visible effect in a few hours. Remembering that several million molecules of an acid could be placed side by side in a line less than one centimetre in length, it will be clear that millions upon millions of such molecules would be necessary to respond to a colour test gauged by the naked eye. Hence such a method breaks down at once. We are bound, therefore, to

\* Such powerful oxidisers as chromic acid are exceptional in their behaviour, however, as they render the iron passive. See Friend, *op. cit.*, p. 9.

arrive at our conclusions in a more or less indirect manner, and hence arises so much uncertainty. In my previous paper \* I have given a detailed account of experiments performed in two glass bulbs connected together internally, but hermetically sealed from the air. One bulb contained sodium hydroxide, and pure  $\text{CO}_2$ -free water was distilled from it on to a strip of pure iron in the second bulb. It is a noteworthy fact that, when the water was distilled from the  $\frac{1}{30}$ -normal sodium hydroxide solution, the iron readily rusted, but when the alkalinity was normal, no rusting took place, save at the edges in contact with the glass. This freedom from rust in the latter case is attributed by the advocates of the electrolytic theory of corrosion to the solution, by the distilled water, of some of the alkali from the glass, whereby the number of hydroxyl ions was increased, and the number of hydrogen ions proportionately reduced. But if such was the case, the same source of alkalinity should have prevented the formation of rust, when the  $\frac{1}{30}$ -normal sodium hydroxide solution was used. But it did not, and the explanation is thus seen to break down.

According to the acid theory, on the other hand, a ready explanation is forthcoming. It need not, however, be repeated here, as it has already received full treatment in the paper referred to.†

Again, in all experiments hitherto published, in which iron is said to rust in contact with pure oxygen and water, it is easy to show that sufficient precautions have not been taken to make the removal of all traces of acid an absolute certainty. Thus Tilden‡ overlooks the fact that barium hydroxide has a very definite equilibrium pressure of carbon dioxide. He also assumes that, by merely warming an exhausted glass tube, every trace of adherent air can be removed from its surface. But numerous researches of recent date have shown that such is far from being the case. The experiments of Dunstan, Jowett, and Goulding§ are open to similar criticism.

\* *Op. cit.*, p. 13.

† *Op. cit.*, p. 15.

‡ *Transactions of the Chemical Society* 1908, vol. xciii. p. 1356.

§ *Ibid.*, 1906, vol. lxxxvii. p. 1548.

My experiments show, however, that when all the necessary precautions are taken, corrosion does not take place. It seems to me, therefore, that the balance of evidence is decidedly in favour of the acid theory. In the paper already referred to, after quoting my statement "that the electrolytic theory of corrosion is untenable," Dr. Walker remarks that "if Dr. Friend's observation be correct, which the author does not admit—namely, that this small amount of carbonic acid is necessary to the solution of the iron—this fact does not contradict the electrolytic theory, but can best be explained, and in truth can be explained only, by the use of the electrolytic theory." It is clear that Dr. Walker fails to distinguish between "the electrolytic theory of corrosion" and what is generally understood by the "electrolytic theory" in its wider application. As we have already seen, the former is based on the assumption that water is ionised to a sufficient extent to cause the corrosion of iron in the presence of oxygen, even though no trace of acid is present. My conclusion is that an acid must be present. But I agree with Dr. Walker when he says that the acid theory of rusting is in harmony with the "electrolytic theory," where by that expression he refers to the theory as enunciated by Arrhenius in its widest sense. The criticism is thus seen to be based on a misunderstanding and falls to the ground.

It may be well to call attention at this juncture to the fact that the ionisation of water, which forms the base of the electrolytic theory of corrosion, is purely an assumption for which we have no definite proof. Kohlrausch showed many years ago that water offers the greater resistance to the passage of an electric current the more carefully it is purified. A limiting value can, however, be reached, below which the conductivity cannot be reduced. Kohlrausch and Heydweiller\* distilled water repeatedly in platinum vessels in vacuo, and determined the conductivity as soon as the water was condensed. At 18° C. the value was  $0.0384 \times 10^{-6}$  ohms per centimetre, from which we calculate the ionic

\* *Zeitschrift für physikalische Chemie*, 1894, vol. xiv. p. 317; *Wied. Ann.*, 1894, vol. liii. p. 209.

concentration to be  $0.78 \times 10^{-7}$  gramme ions per litre.\* It is noteworthy that simple contact with air raised its conductivity tenfold in a very short time.†

Now although this water was undoubtedly the purest which has ever been obtained, we have no proof that it was absolutely pure. Not a few chemists maintain that if absolutely pure water could be obtained, it would be found to be incapable of conducting an electric current—in other words, that it would be incapable of ionisation. Leduc‡ has drawn attention to the extreme difficulty of removing every trace of dissolved gases from water by boiling, and a very few molecules of carbon dioxide would be ample to give to an absolutely non-conducting specimen of water the minute conductivity observed by Kohlrausch and Heydweiller; so that their results may simply be a measure of the extent to which the dissolved gases remain in solution under the special conditions of the experiments. If such is really the case, the electrolytic theory of corrosion becomes a myth, whereas the acid theory is unaffected by it.

In this connection I should like to draw attention to the fact that, whilst Dr. Walker's ferroxyl is undoubtedly a useful reagent when rightly used, no experiments with ferroxyl in actual contact with metallic iron can be quoted as deciding between the acid and electrolytic theories of corrosion, for its constituents are complex organic bodies which it is impossible to prepare in an absolutely neutral condition.

From the preceding remarks it will be clear that the whole question resolves itself into this: Is pure water sufficiently active to effect the corrosion of pure iron in the presence of oxygen alone at ordinary temperatures, or is it not? Dr. Walker supplies the answer most decidedly in the affirmative, but my experiments lead me to an opposite conclusion. But either view is in harmony with the electrolytic theory of ionisation as we now know it, and the solution of the problem is one of theoretical rather than practical value.

\* Nernst, "Theoretical Chemistry," translated by Leffeldt, 1904, p. 509.

† Kohlrausch, *Zeitschrift für physikalische Chemie*, 1902, vol. xlii. p. 193.

‡ *Comptes Rendus*, vol. cxlii. p. 149.

## VISITS AND EXCURSIONS AT THE LONDON MEETING.



IN connection with the London Meeting, an influential Local Reception Committee was formed to make arrangements to receive and entertain the members. The constitution of this Committee, which was composed of members of the Institute resident in the Metropolitan area and of firms connected with the iron and steel trades having offices in London, was as follows :—

### GENERAL RECEPTION COMMITTEE.

#### *Chairman.*

Sir HUGH BELL, Bart. (President).

#### *Patrons.*

Adams, George, & Sons, Ltd.	Colville, David, & Sons, Ltd.
Allen, Edgar, & Co., Ltd.	Consett Iron Co., Ltd.
Applebys, Ltd.	Cooke, Wm., & Co., Ltd.
Armstrong, Sir W. G., Whitworth & Co., Ltd.	Darlington Forge Co., Ltd.
Baldwins, Ltd.	Dorman, Long & Co., Ltd.
Barrow Haematite Steel Co., Ltd.	Earl of Dudley's Round Oak Works, Ltd.
Bayliss, Jones & Bayliss, Ltd.	Ebbw Vale Steel, Iron, and Coal Co., Ltd.
Beardmore, William, & Co., Ltd.	Farnley Iron Co., Ltd.
Blaenavon Company, Ltd.	Firth, Thos., & Sons, Ltd.
Bolckow, Vaughan & Co., Ltd.	Fox, Samuel, & Co., Ltd.
Braby, Fred., & Co., Ltd.	Glengarnock Iron and Steel Co., Ltd.
British Mannesman Tube Co., Ltd.	Guest, Keen & Nettlefolds, Ltd.
Brotherhood, Peter, Ltd.	Hadfield's Steel Foundry Co., Ltd.
Brown, John, & Co., Ltd.	Hall & Pickles.
	Hardy Patent Pick Co., Ltd.

Heath, R., & Sons, Ltd.	Otto-Hilgenstock Coke Oven Co., Ltd.
Hickman, Alfred, Ltd.	Park Gate Iron and Steel Co., Ltd.
Hirsch & Co., Ltd.	Raine & Co., Ltd.
Hurst, Nelson & Co., Ltd.	Redpath, Brown & Co., Ltd.
Jessop, William, & Sons, Ltd.	Scott, Walter, Ltd.
Lanarkshire Steel Co., Ltd.	Shelton Iron, Steel, and Coal Co., Ltd.
Lilleshall Co., Ltd.	Steel Company of Scotland, Ltd.
Lloyd, F. H., & Co., Ltd.	Steel, Peech & Tozer, Ltd.
Metropolitan Amalgamated Railway Carriage and Wagon Co., Ltd.	Stewarts & Lloyds, Ltd.
Monk Bridge Iron and Steel Co., Ltd.	Summerscales, W., & Sons, Ltd.
Newton, Chambers & Co., Ltd.	Taylor Bros. & Co., Ltd.
Old Castle Iron and Tinplate Co., Ltd.	Vickers, Sons & Maxim, Ltd.
	Whitwell, Wm., & Co., Ltd.

*Members of Committee.*

His Grace the Duke of Devonshire (President-Elect).  
The Lord Airedale of Gledhow (Past-President).  
The Lord Stanley of Alderley.  
Sir R. A. Hadfield (Past-President).  
Sir A. Hickman, Bart. (Member of Council).  
Sir Alex. B. W. Kennedy.  
Sir Joseph Lawrence.

Ablett, C. A.	Fox, E. Marshall.
Acland, F. E. D.	Gielgud, H.
Agius, E. T.	Gilchrist, Percy C., F.R.S. (Vice-President).
Agius, J. C.	Gillespie, John (London).
Angus, J.	Gowland, Prof. W., F.R.S.
Appleby, C. T.	Gurney, R. F.
Baillie, J. R.	Haeberlin, F.
Bamber, H. Kelway.	Hahn, C. Alfred.
Bauerman, Prof. H. (Hon. Member).	Hall, B. J.
Bird, Clarence.	Harbord, F. W.
Booth, Robert.	Harris, H. Graham.
Braby, Cyrus.	Hawksley, Charles.
Braby, Frederick.	Hay, W. R.
Braby, Ivon.	Hayne, W. Crosier.
Brophy, M. M.	Head, B. W.
Brown, P. B.	Heap, J. H.
Carlisle, Edwin.	Hesketh, E.
Cawley, G.	Hethy, G.
Chalas, E. C.	Hiby, W.
Church, R. F.	Holliday, H.
Cleaves, F.	Horne, J. W.
Commans, R. E.	Hughes, J. W.
Constantine, E. G.	Hunsiker, Colonel M.
Cordner-James, J. H.	Hunt, C.
Cornish, J. H.	Huntington, Prof. A. K.
Corrie, J. B.	Hurtzig, A. C.
Cowan, Colonel J. H.	Jeans, Harold.
Cowper-Coles, S.	Jeans, J. Stephen.
Craddock, T. F.	Jones, W. E.
Cross, William.	Justice, P. M.
Cross, Wilson.	Kirkaldy, W. G.
Custodis, A.	Korten, M.
Custodis, J. C.	Law, Edward F.
Davison, John.	Ledingham, J. M.
Dewrance, John.	Levick, Frederick.
Donaldson, H. F., C.B.	Levy, Lewis.
Dore, S. L.	Livesey, James.
Downe, Henry S.	Mackay, H. J. S.
Ekenberg, Dr. M.	McNeill, Bedford.
Etherington, John.	Malmberg, O. A.
Ferguson, Major V.	Maw, W. H.
Flett, G.	

Melling, J. F.  
 Merrett, W. H.  
 Meyjes, A. C.  
 Middleton, J. T.  
 Milton, J. T.  
 Mond, Emile S.  
 Moore, Alfred.  
 Moore, Harold.  
 Mordey, W. M.  
 Morgan, Lieut.-Col. A. H.  
 Morgan, G. Vaughan.  
 Morgan, S. Vaughan.  
 Murray, M.  
 Negus, W.  
 Nesbit, D. M.  
 Pearson, W. H.  
 Peech, W. H.  
 Pendred, V.  
 Pratt, A. E.  
 Prest, S. F.  
 Price-Williams, R.  
 Pye-Smith, Arnold.  
 Randall, J.  
 Reichwald, A.  
 Ritchie, G. Mure.  
 Roberts, G. H.  
 Robertson, Leslie S.  
 Robinson, J. F.

Robinson, Mark.  
 Roe, J. Pearce.  
 Rosenhain, W.  
 Rosenthal, J. H.  
 Sandberg, C. P.  
 Scott, H. Kilburn.  
 Serena, A.  
 Sherley-Price, E. A.  
 Siemens, Alex.  
 Skaife, Walter.  
 Smeeton, J. A.  
 Smith, J. J.  
 Spannagel, H.  
 Stanger, R. H. H.  
 Sterne, Louis.  
 Sumner, E. H.  
 Thearle, S. J. P.  
 Thomas, F. T.  
 Thomas, R. Beaumont.  
 Touche, J. E.  
 Turner, H. G.  
 Walber, W. A.  
 Walmisley, A. T.  
 Wedekind, H.  
 Whigham, H. T.  
 Wise, Sir Lloyd.  
 Wood, E. M.  
 Young, Septimus.

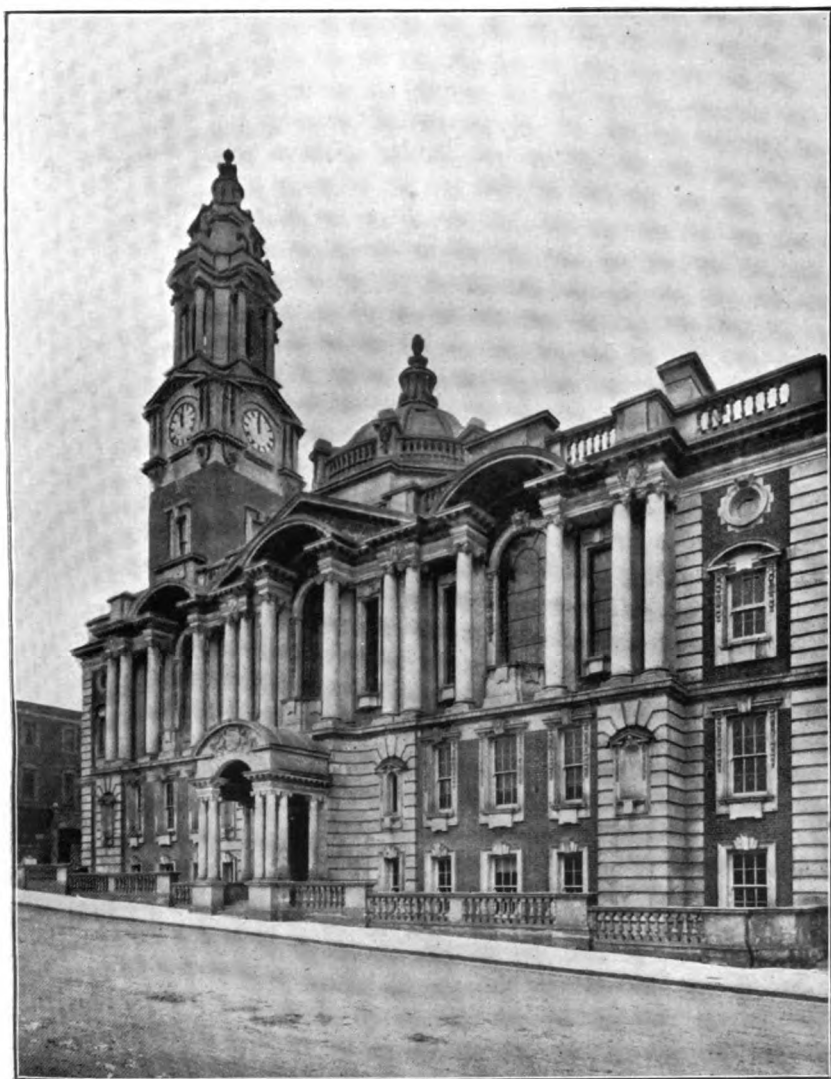
The Executive Committee consisted of the following members of the Reception Committee :—

Chairman, Sir Hugh Bell, Bart. ; Sir Robert A. Hadfield, Sir W. Lloyd Wise, J. Angus, P. B. Brown, Edwin Carlisle, R. E. Commans, J. Dewrance, Dr. M. Ekenberg, F. W. Harbord, Professor A. K. Huntington, Harold Jeans, W. G. Kirkaldy, E. F. Law, O. A. Malmberg, J. F. Melling, A. C. Meyjes, Matthew Murray, Arthur E. Pratt, Leslie S. Robertson, A. Serena, W. A. Walber, Septimus Young, and G. C. Lloyd (Secretary).

Preparations were made on a considerable scale as the number of members signifying their intention of attending was unprecedentedly large. Owing, however, to various causes, amongst which must doubtless be included the inclemency of the weather, the number of members and ladies who registered their names was somewhat lower than the number anticipated, although, notwithstanding the diminution, over a thousand attended.

The Secretary's office was at the St. Ermin's Hotel, Westminster, where a suite of rooms was taken on the ground floor of the west wing. These rooms consisted of an office for the registration of members and for the issue of official programmes and of the various souvenirs and tickets prepared in connection with the meeting, while a large writing-room was provided for the convenience of the members, and a special telephone installed. The selection of the St. Ermin's Hotel as a centre for the meeting was influenced by a consideration of its convenience as a place of assembly and its proximity to the St. James's Park Station of the District Railway, with which it is connected by a covered passage. The offices remained open during the whole period of the London meeting, and many of the members availed themselves of the facilities afforded.

The badge presented to the members by the Reception Committee was artistically executed in red and white enamel, and bore the Arms of the Institute with the inscription : "Iron and Steel Institute, London, 1909." Members of the Executive Committee wore this badge in conjunction with



WOOLWICH TOWN-HALL





PLATE XIX

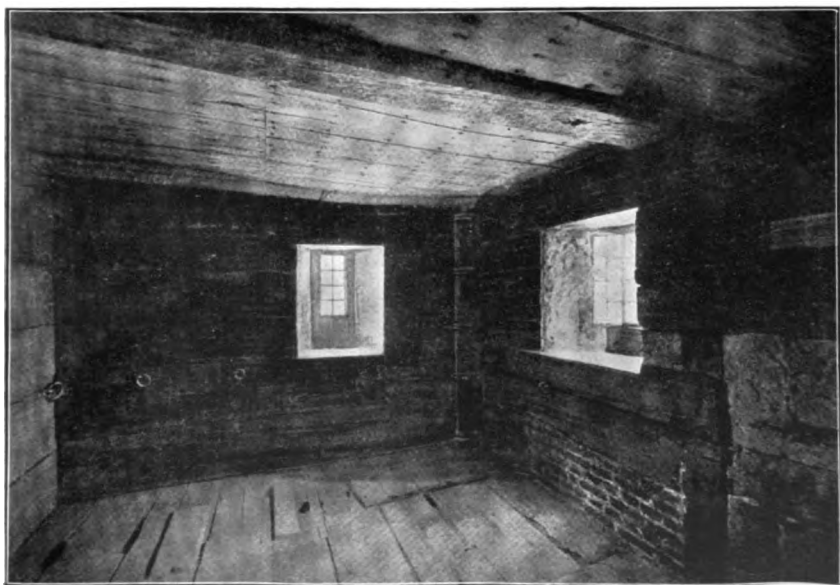


MEMBERS OF THE IRON AND STEEL INSTITUTE AT THE MITCHELL MOTOR WORKS AND GARAGE.





LAMBETH PALACE



THE PRISON IN THE LOLLARDS' TOWER, LAMBETH PALACE



a rosette of red and white silk, red and white being the colours of the City of London. Members of Council were provided with a bar bearing the inscription "COUNCIL" in gold letters upon a background of white enamel, from which the badge was worn suspended.

In addition to the official programme of the meeting a pictorial and descriptive guide to London and its environs, bound in green cloth and containing over 100 illustrations and several maps and plans, was presented to each of the members attending.

The mornings of Tuesday, Wednesday, and Thursday, the 28th, 29th, and 30th of September, were devoted to the reading and discussion of papers in the theatre of the Institution of Civil Engineers, Great George Street, Westminster, which had been generously placed at the disposal of the Iron and Steel Institute for the occasion.

On the afternoon of Tuesday, September 28, visits were paid to the works of Messrs. Siemens Brothers & Company, Ltd., Woolwich, to the Royal Arsenal, Woolwich—by permission of the Army Council—and to the works of Messrs. Fraser & Chalmers, Ltd., Erith. Visits were also arranged to the London County Council Electric Generating Station, Greenwich, and the Central Repair Depôt of the Council at Woolwich, to the Hall of the Worshipful Company of Armourers and Brasiers, and to the Hall of the Worshipful Company of Ironmongers.

On the evening of Tuesday, September 28, over 900 of the members and ladies accompanying them attended a gala performance at the Lyceum Theatre of the romantic play by Mr. Justin Huntly McCarthy, entitled "The Proud Prince." The vestibule and the interior of the theatre was tastefully decorated with flowers for the occasion, and an artistic programme, bearing the Arms of the Institute, was supplied by the management. As a souvenir of the occasion each of the ladies attending was presented by the Reception Committee with a box of bon-bons. The warm thanks of the Committee are due to the managing directors and to Mr. W. F. Crowe for the pains taken to render the evening a success. The principal rôle in the play was sustained by Mr. Matheson Lang, who enacted the part of King Robert of Sicily, the play itself being based on the legend respecting that monarch recounted in Longfellow's "Tales of a Wayside Inn." His Grace the Duke of Devonshire, President-Elect, was present throughout the performance.

On the afternoon of Wednesday, September 29, visits were arranged to the National Physical Laboratory, Teddington; to the Motor Car Works of Messrs. D. Napier & Son, Ltd., Acton, and the Mitchell Motor Works and Garage, Soho; to Lambeth Palace and the Royal Doulton Potteries, Lambeth; to the Royal Small Arms Factory, Enfield, by permission of the Army Council; to the Royal Mint, by permission of the Master of the Mint; and to the Power Plant Co., Ltd., West Drayton, Middlesex.

On the evening of Wednesday, September 29, the members and ladies accompanying them were entertained at dinner informally by the Reception Committee at the Trocadero Restaurant, Shaftesbury Avenue. A large attendance was anticipated, but the alternative arrangements for the same evening proved somewhat more attractive to many of the members, and only a little over 300 persons were present.

The chair was occupied by Sir Hugh Bell, Bart., Chairman of the Reception Committee, and the assembled company included Lord Glantawe of Swansea; Mr. W. Graham Greene, C.B.; Mr. A. T. Tannett-Walker, Vice-President; the Hon. A. E. Kitson; Mr. George Ainsworth, Member of Council; Mr. Alexander Siemens and Miss Siemens; Mr. Andrew Lamberton, Member of Council, and Mrs. Lamberton; Dr. R. T. Glazebrook; Mr. A. L. C. Fell; Mr. E. Saladin (Paris); Mr. W. Dieselhorst; Mr. W. F.

Rainforth; Mr. James B. Mitchell; Mr. O. Christen (Witkowitz); Mr. Lucien Arbel (Paris); and Mr. F. H. Ford.

The programme of music given during the dinner was performed by Mr. A. H. Pitman's Blue Viennese Orchestra, and on the conclusion of the repast the usual loyal toasts were duly proposed by the President, and the remainder of the evening was devoted to a vocal concert carried out under the direction of Mr. Harrison Hill, assisted by Miss Irene Spong, Miss d'Auvergne Upcher, Mr. Franklin Clive, and Mr. Ernest Mills, the accompanist being Mr. Herbert Cook.

As the number of members who had signified their intention of attending the meeting was very greatly in excess of that which it would have been possible to accommodate at the Trocadero, arrangements had been made by the Reception Committee for their entertainment at His Majesty's Theatre, where the whole of the stalls had been engaged to enable them to witness a performance of the spectacular drama "False Gods," translated by J. B. Fagan from the French drama "La Foi," by Brieux, with music specially composed by Saint-Saëns. The theatre was florally decorated for the occasion, and a special programme and souvenir, containing beautiful photographic reproductions of some of the principal scenes in the play, was provided by the management, to whom the thanks of the Reception Committee are due for the completeness and excellence of the arrangements. Even this accommodation proved, however, inadequate for the whole of the party, and, in addition to over 400 seats booked at His Majesty's, 50 seats were secured at the Vaudeville Theatre, to witness a performance of Mr. F. Anstey's new farcical play, "The Brass Bottle."

On the afternoon of Thursday, September 30, a visit was paid to the Mercers' Hall, Cheapside, by invitation of the Master and Wardens of the Company, and, later on in the afternoon, a Reception was held at the Mansion House. The Lord Mayor (the Right Hon. Sir George Wyatt Truscott) was unfortunately prevented from attending at the commencement of the function, although he arrived later. In his absence the Lady Mayoress received the guests. Music was provided in the Egyptian Hall, and the members, on the conclusion of the Reception, were entertained to tea and light refreshments at the buffet. About 800 persons were present, and the function proved, in every way, highly successful, and was much appreciated by those attending.

The Reception at the Mansion House concluded the arrangements made for the entertainment of the members within the Metropolis itself, and Friday, October 1, the last day of the meeting, was devoted to a special excursion to the Dockyard and to His Majesty's Naval Establishments at Portsmouth. A special Pullman car express was chartered for the journey, and luncheon served at the Dockyard soon after arrival.

## NOTES ON WORKS VISITED.

### VISIT TO THE WORKS OF MESSRS. SIEMENS BROTHERS & CO., LTD., WOOLWICH.

About 70 members visited the works of Messrs. Siemens Brothers & Co., Ltd., at Woolwich, on the afternoon of Tuesday, September 28. Mr. P. B. Brown and Mr. O. A. Malmberg, members of the Reception Committee,

acted as stewards. The party travelled by special train from Charing Cross, and on arrival at Charlton Junction were met and conveyed to the works in brakes kindly provided by the management. On reaching the gates they were received by Mr. Alexander Siemens, Director, who, in company with Miss Siemens, had journeyed with the party on the train from Charing Cross, and by Mr. Dieselhorst, the General Manager, Mr. Laukert, Mr. Forrest, and Mr. Jacob, managers of various departments, who, with the assistance of other members of the staff, conducted the visitors through the works. After the inspection had been completed, refreshments were served in the cable warehouse. Before leaving, Mr. G. C. Lloyd, Secretary of the Institute, expressed the thanks of the members to the Company for so kindly throwing open their works.

The Woolwich Works were established in 1864, and now cover an area of about 15 acres. The dynamo and motor part of the business was transferred to Stafford in 1904, and the works are now principally engaged in the manufacture of electrical cables, signalling and measuring apparatus of all descriptions. The works are equipped with an extensive and up-to-date plant for the manufacture of submarine cables, including high-speed cable-making machines and large tank-houses. Besides many other cables, these works have turned out nine cables across the Atlantic. The company own the cable twin-screw s.s. *Faraday*, 360 feet long and 52 feet beam, 10,000 tons displacement when fully loaded.

The shops for the manufacture of electric light and power wires and cables are equipped for turning out every description of rubber, fibre, or paper insulated conductors, the rubber being received in the raw state and undergoing all the necessary processes at the works.

The paper cable shops in particular, where telephone cables of the largest kind are made, are arranged in the most modern way, and fitted with special machinery for stranding, twinning, and lead covering.

In addition to rubber for cables, the company make ebonite sheets and moulded goods for batteries, &c.

The battery and line material department include shops for the manufacture of fluid and dry batteries of all descriptions, carbon plates, and telegraph line material.

Situated close at hand are the extensive wood-working and cabinet shops, which make not only the wooden parts required for the various apparatus, but also public telephone call-boxes, office furniture, &c., on a large scale.

The apparatus department occupies a building of three floors, comprising tool, machine, and fitters' shops, as well as the railway signalling shop. These are provided with modern machinery, and are engaged in the manufacture of telegraph, telephone, and electrical measuring instruments, projectors, torsion meters, and signalling apparatus of all kinds, with the attendant processes of lacquering, tinning, plating, polishing, &c. &c.

On the other side of the yard are the instrument calibrating and testing departments, which are equipped with special testing plant and switchboards.

The whole of the machinery in the works is electrically driven, power being supplied by a station containing five 300 horse-power high-speed engines direct coupled to Siemens dynamos.

Goods are conveyed between the line department and the wharf by electric telfer, and elsewhere by narrow gauge tramway.



## VISIT TO THE ROYAL ARSENAL, WOOLWICH.

*(By permission of the Army Council.)*

Of the 325 members who travelled down to Woolwich by the special train leaving Charing Cross at 1.30 P.M. on the afternoon of Tuesday, September 29, nearly 200 had chosen Woolwich Arsenal as their destination. Mr. W. G. Kirkaldy and Mr. Septimus Young, members of the Reception Committee, accompanied the party, which detrained at Woolwich Arsenal Station, and was escorted by members of the local constabulary, under the superintendence of Inspector Mott, from the station to the main gates of the Arsenal. On arrival at the Arsenal the party was received by Mr. H. F. Donaldson, C.B., Chief Superintendent of the Ordnance Factories, and was divided into seven groups, one member of each group signing the official visitors' book on behalf of the contingent to which he belonged. The first party was personally conducted by Mr. Donaldson, and included Mr. A. T. Tannett-Walker, Vice-President, and Mr. George Ainsworth, Member of Council, and thereafter the remaining contingents followed in quick succession, each member being provided with an itinerary showing the route and the times for arriving at the different points of the tour. The inspection commenced with a visit to the Main Factory of the Royal Laboratory Department, which contains machine tools for the manufacture of fuse parts, and their assemblage, and the members subsequently proceeded through the various factories and workshops. Much interest was evinced by the visitors in the Tropenas process as conducted at the Arsenal, and some time spent in witnessing a blow in the Shell Foundry, in which the converter plant is housed, and in which the whole of the crane equipments for ladles, moulds, &c., is electrical. The Tropenas process was adopted in the Shell Foundry in 1897, the installation being one of the first of its kind in this country. The charge is about 2 tons, and the molten pig iron used contains from 4 per cent. to 5 per cent. of carbon. Blowing occupies from fifteen to twenty minutes, the particular point at which the whole of the carbon is burnt out being very well marked. The converter is then turned down and the required additions made according to the particular nature of steel it is desired to produce. It is then turned up again, and when the additions have been thoroughly incorporated and combined with the molten metal, the converter is again turned down and the charge poured into a ladle, whence it is taken by electric crane to the casting pits and poured into the moulds prepared for it.

The Royal Arsenal, Woolwich, occupies the site of an ancient Roman settlement. In later times a large and important dockyard existed in the locality, and during the reign of James I. many of the largest warships of the British Navy were built at Woolwich. The dockyard, however, ceased to exist as such in 1869. As early as the seventeenth century the Royal Carriage Department and the Royal Laboratory were in operation, and ordnance was proved at Woolwich, but the establishments were not officially described as the Royal Arsenal until 1805. Up to the year 1856 convict labour was largely used in the extension works, and the remains of prisoners have been found in the course of excavations, in some cases with their shackles still attached.

The chief military and naval establishments located within the boundaries of the Royal Arsenal are the Army Ordnance Department, the Army Inspection Department, and the Naval Ordnance Department; the Ordnance Factories being the most important portion shown to visitors.

These comprise the Royal Laboratory, the Royal Carriage Department, the Royal Gun Factory, and the Building Works Department, which, together with the Gunpowder Factory at Waltham Abbey and the Small-Arms Factory at Enfield Lock, are collectively known as the Royal Ordnance Factories.

The Arsenal is over 3 miles in length and a mile broad, the total area amounting to about 1285 acres, of which 407 acres are contained within the boundary walls, and 89 acres are covered with buildings. The total horse-power available is 9700. There are 15 miles of broad gauge railway, served by 19 locomotives and 300 waggons, and 32 miles of narrow gauge railway with 40 steam locomotives, 5 oil locomotives, and 986 trucks. The properly organised passenger service is a feature of this railway system, there being 14 trains daily in each direction, from end to end of the Arsenal, stopping at 10 stages *en route*, and running at regular times. The main avenues within the Arsenal are laid with asphalt tracks for cycle traffic.

While the number of persons employed varies considerably, according to circumstances, the average during the ten years ending 1906 has been roughly 16,000.

The chief buildings and workshops are as follows :—

#### ROYAL LABORATORY.

*Main Factory*, for the manufacture of ammunition of all kinds. This factory contains 600 machine tools, amongst which are 80 automatic machines of the most modern type.

*Pattern Room*, containing an interesting collection of warlike stores dating from early days of ordnance manufacture.

*Small-Arms Bullet Factory*, for the manufacture of rifle bullets, consisting of a soft lead core and an envelope.

*Quick-firing Cartridge Factory*, in which several operations are conducted, such as mixing and casting ingots of special composition, rolling these ingots into strips and punching the strips into blanks, the conversion of the blanks into cups and the elongation of the cups by drawing, and finally the formation of shoulders on the drawn cases with the subsequent minor machine operations. The machinery is mostly hydraulic, the pressure employed ranging up to 3 tons per square inch.

*Shell Foundry*.—In this establishment the bodies of the various natures of shot and shell are produced and manipulated previous to being filled with explosive charges, or fitted into quick-firing charges. The equipment comprises eleven cupolas for the production of iron castings and molten iron for conversion to steel, underground furnaces for the production of crucible cast-steel shells, and three Tropenas converters for the production of the larger sizes of cast-steel shell.

#### ROYAL GUN FACTORY.

*North Boring Mill*.—This is one of the older sections of the factory wherein guns of all classes and calibre are manufactured, except small-arm rifles and machine guns. There are in the department about 180 electric motors with an aggregate horse-power of 2800. The current is supplied from the Central Power Station for the Arsenal generally, and a considerable use is made in this factory of magnetic clutches.

*Field Gun Section*.—In this section are manufactured the lighter mobile guns used by the Horse and Field Artillery.

The other departments of the Royal Gun Factory consist of the main turnery shops, the forge, and the South Boring Mill, where the rifling of large guns is carried out.

#### ROYAL CARRIAGE DEPARTMENT.

*Main Machine Shop.*—The tools in this section are among the largest of their kind in the Royal Arsenal, and many of the operations performed approximate more to ordinary engineering work than in other shops through which the visitor has passed.

*Wheel Factory.*—In this factory will be seen some of the most modern and ingenious machines in use in this country for wheel construction. The various parts of the wheel are assembled by means of hydraulic presses. This machinery is also used for making heel-pegs, tent-poles, and mallets.

*Carpenters' Shop.*—This contains the fellow bending machine and the hydraulic presses for clamping together boxes and chests.

*Whealers' Shop.*—In this shop will be found, in various stages of construction or repair, examples of many military waggons, carts, and limbers.

*Wood Machine Shop.*—This shop contains a number of wood-working machines. In accordance with modern practice these are driven from underground, and shavings, chips, and dust are also drawn away underground by means of exhaust ducts.

#### VISIT TO WOOLWICH TOWN HALL.

On the conclusion of the visit to Woolwich Arsenal, the members proceeded to the Town Hall, where they were received by His Worship the Mayor of Woolwich (Mr. George Whale), who was accompanied by his Mace-bearer and by Mr. Arthur B. Bryceson, the Town Clerk, and Sir A. Brumwell Thomas, the architect of the Town Hall, who explained the chief architectural features of the building. The party was conducted round the principal rooms and the gallery surrounding the Entrance Hall, and were entertained at tea in the suite of Committee Rooms situated over the main entrance, when the Town Clerk imparted some interesting details concerning the history of the borough. At the conclusion of the repast a cordial vote of thanks was, on the motion of Professor Thomas Turner, seconded by Mr. Joseph Harrison, unanimously passed by those present, and suitably acknowledged by the Mayor, after which the visitors departed for the station, to join the special train which was to take them back to town.

The Town Hall, Woolwich, is situated in Wellington Street, in the immediate vicinity of the chief public buildings of the locality. Its principal façade is 114 feet long, and the depth is 230 feet. It was built from the designs of Sir A. Brumwell Thomas, the architect, and the foundation-stone was laid on 13th May 1903, the building being opened on 13th January 1906. The Entrance Hall is 100 feet long by 40 feet wide and 45 feet high, and is surmounted by three domes enriched with plaster decoration. In the centre of the Hall stands a statue of Queen Victoria, executed by Mr. Frederick Pomeroy, A.R.A., which was erected by voluntary public contributions. The window over the staircase is a fine piece of stained glass, illustrating a visit of Charles I. to Woolwich, and

Phineas Pett, Master Shipwright, presenting the monarch with plans of the great ship *Sovereign of the Seas*. The inscription is as follows:—

“Here, in the month of October 1637, Phineas Pett, the master ship-builder, having fixed the rigging and sails at the yards, conducted King Charles 1st on board H.M.S. *Sovereign of the Seas* before her final departure from Woolwich & the King is mightily pleased. H.M.S. *Sovereign of the Seas*, whose burden was 1637 tons, being the very number of the year of her launching, was 127 feet long by the keel and 47 feet broad by the beam. Her building lost the King the affection of many of his subjects who rebelled against the levy of ship-money.”

In the Council Chamber are three other windows, the centre bearing the present Royal Arms, and the other two representing Henry VIII. and Queen Elizabeth respectively. It is interesting to note in connection with the historical associations of Woolwich the inscriptions on these two windows which commemorate the building in 1512 of the *Great Harry*, which conveyed Henry VIII. to the Field of the Cloth of Gold, and the launching of the *Elizabeth* in 1559 in that queen's presence. This vessel was afterwards commanded by Sir Robert Southwell against the Armada. The historical associations of Woolwich extend, however, to much earlier days, and the window in the Central Committee Room commemorates Eltham Palace, in which, as far back as 1364, King Edward III. entertained John, King of France, David Bruce of Scotland, and Waldemar of Denmark, at a banquet. The celebrated Samuel Pepys for some time occupied a residence in Woolwich, and, as Secretary to the Admiralty, was closely connected with the Dockyard and Ropehouse.

The Public Hall can accommodate 850 persons, and is admirably designed from an acoustic point of view. It contains a memorial window to Richard Lovelace, the cavalier poet, who was born at Woolwich in 1618. Among other memorial windows is one to Henry Maudeslay, who invented the Slide Rest, and to General Gordon, who was born at Woolwich.

#### VISIT TO THE WORKS OF MESSRS. FRASER & CHALMERS, LTD., ERITH.

Notwithstanding the unfortunate weather, 50 members of the Institute paid a visit to the works of Messrs. Fraser & Chalmers, Ltd., at Erith, and spent a pleasant and profitable afternoon inspecting the various shops. The visitors travelled by special train from Charing Cross, and were welcomed at Erith by Mr. Walter McDermott, the managing director, and were afterwards conducted in small parties through the works by various members of the staff. In the machine, erecting, and boiler shops the visitors found much to interest them, but the chief attraction was the turbine shop, in which several turbines were in course of erection. During the afternoon a practical demonstration was given of the economical firing of the “Bettington” boiler for burning dust fuel. At the conclusion of the visit tea was served in one of the large rooms adjoining the turbine shop, and a hearty vote of thanks was accorded the company on the motion of Mr. F. W. Harbord, member of the Reception Committee, who accompanied the party on this excursion. Mr. Walter McDermott having replied on behalf of the company, the visitors returned to London by a special train leaving Erith at 5.12 P.M.

The works of Messrs. Fraser & Chalmers, Ltd., are situated on the Thames at Erith, Kent, with wharf for river shipment, and connection with the lines of the South-Eastern and Chatham Railway. The shops were begun in 1890, and have been gradually enlarged and added to until now a force of over 1400 men is employed. Up till 1901 the company also owned works in Chicago, and shipments were made partly from America and partly from Erith. At present the whole of the company's manufacture is concentrated at Erith. The English company was formed for the purpose of establishing in England the manufacture of high-class modern mining machinery, and as a first step thereto the then well-known American business of Fraser & Chalmers was bought, and later was sold when it had served its purpose of building up the English trade. The shops are fitted with modern tools of the best types built in England, United States, and Germany, and special provision has been made for the erection and testing of large engines, pumps, and compressors. The tools and testing floor for the manufacture of high and low pressure steam turbines of the Rateau type, put down in 1905, have produced over forty of these machines which are now in use. The large area of the boiler shop allows of the complete erection under cover of the largest size of gold dredges. Among the great variety of machinery which is made at Erith, the following may be mentioned as receiving special attention and representing special experience in manufacture. Driving engines, compound hoisting engines, Whiting hoists, Riedler and Gutermuth pumps and compressors, crushers, stamp mills, grinding pans, tube mills, cyanide plants, concentration mills, Wilfley tables and slimers, frue vanners, smelting furnaces, Bessemer converter plants, roasting furnaces, Blaisdell excavators, continuous filters, coal screening and washing plants, coaling plants, conveyor installations, boilers, Rateau steam turbines, Rateau centrifugal pumps and turbo compressors, ventilator fans, diamond washing plants, heavy American type of gold dredges, and the necessary accessories for the various plants.

A new type of boiler for burning dust fuel, known as the Bettington boiler, is in use at the works, and is now being introduced elsewhere. Its high efficiency and power of using inferior slack with as much as 30 per cent. of ash, marks out a special field for its employment.

#### VISIT TO THE LONDON COUNTY COUNCIL ELECTRIC GENERATING STATION, GREENWICH.

On the afternoon of Tuesday, September 28, a party of members and ladies accompanying them assembled at the Westminster Bridge end of the Thames Embankment, in order to participate in the visit to the London County Council's Electric Generating Station at Greenwich. Mr. Matthew Murray, member of the Reception Committee, and Mr. W. F. Cheesewright acted as stewards for the party, which was conveyed by special tramcars to Greenwich, where it was met at the Generating Station by Mr. A. L. C. Fell, chief officer of the tramways. After inspecting the plant and installation at the Station, the cars took the members on to the Central Repair depot at Woolwich, at the conclusion of the inspection of which they were entertained to tea and light refreshments. Before leaving, Mr. Matthew Murray proposed, in suitable terms, a vote of thanks to Mr. Fell and to the Council for their kindness in inviting the members, which was acknowledged on behalf of the County Council by Mr. Fell. The visitors were then re-conducted to Westminster Bridge by the special cars.

The Greenwich Electricity Generating Station, which was opened on

May 26, 1906, has been designed to supply sufficient energy for the whole of the tramways worked by the London County Council. It will be one of the largest generating stations in the kingdom, and will ultimately have plant amounting to about 52,000 horse-power. The general arrangement of the generating station was designed by the Council's architect in consultation with the tramways electrical engineer, and the building was erected under the supervision of Mr. W. E. Riley, the Council's architect, and equipped under the supervision of Mr. A. L. C. Fell, the Council's chief officer of tramways, and Mr. J. H. Rider, the tramways electrical engineer. The pier and condensing water pipes were designed and erected under the supervision of Mr. Maurice Fitzmaurice, the Council's chief engineer. The site is on the bank of the river at Greenwich, about 250 yards eastward of Greenwich Hospital. There is an area of approximately  $3\frac{1}{2}$  acres. The boiler-house contains twenty-four water-tube boilers of the five-drum Stirling Company's type, and twenty-four boilers of the Babcock & Wilcox Company's type, arranged in pairs in two rows, with a firing floor between. Each Stirling boiler has an evaporate capacity of about 16,300 lbs. of water per hour, while the Babcock boilers will evaporate 18,200 lbs. per hour. Each boiler works at 200 lbs. pressure, and is fitted with chain grate stokers. The engine-room contains four reciprocating engine sets of 3500 kilowatts normal capacity each, and two turbine sets of 5000 kilowatts each. Two other sets are in course of erection. The engines are by Messrs. John Musgrave & Sons, Limited, of Bolton, and are of the vertical-horizontal type. Each engine comprises two complete half-engines, one on each side of the generator, consisting of a vertical high pressure cylinder  $33\frac{1}{2}$  inches diameter, and a horizontal low pressure cylinder, 66 inches diameter. The stroke in each case is 4 feet, and the two connecting-rods on the one side of the engine work on to a common overhung crank pin. The engines run at 94 revolutions per minute. The generators were built by the Electric Construction Company, Limited, of Wolverhampton, and are mounted directly on the engine shafts, each generator being erected between the two half-engines of each set. They are all of the revolving field type, and deliver three-phase current at 6600 volts between phases, at 25 complete cycles per second. The normal output is 3500 kilowatts, or 306 amperes per phase, and 4375 kilowatts on emergency overload. The turbines now at work were made by Messrs. Willans & Robinson, Limited, while the generators were made by Messrs. Dick, Kerr & Co., Limited. They run at 750 revolutions per minute, and will give 6250 kilowatts on emergency overload. The switch-gear is of the remote control electrically operated type. The circulating and feed-pumps are all electrically operated. When completed, the Station is estimated to cost about £800,000, and the total cost of the pier condensing water pipes, and a wharf wall about 260 feet in length, is about £53,000.

### VISIT TO IRONMONGERS' HALL.

On the afternoon of Tuesday, September 28, over two hundred of the members and ladies accompanying them visited the Hall of the Worshipful Company of Ironmongers, by invitation of the Master and Wardens. The company assembled, under the guidance of Mr. A. C. Meyjes and Mr. E. F. Law, members of the Reception Committee, at the St. Ermin's Hotel, and were conducted thence to the St. James's Park Station of the District Railway, the newly covered way leading from the hotel to the station being on this occasion used for the first time. The party alighted at Mark Lane Station and proceeded to Fenchurch Street, E.C., where the Hall is situated, the City Police having made special arrangements to facilitate the conduct

of the large numbers attending. On their arrival at Ironmongers' Hall they were received by Mr. Walter T. H. Radford, the Worshipful Master of the Company, who was supported by Sir Ernest F. G. Hatch, Bart., Senior Warden, and Mr. Arthur Birkett, Junior Warden, wearing their robes of office, and by Mr. R. C. Adams-Beck, Clerk of the Company, by whom they were cordially welcomed. Mr. Gwyn Vaughan Morgan, Immediate Past Master, also attended and received the visitors, who were subsequently conducted over the premises. An interesting address was delivered by Mr. E. H. Nicholl, the hon. librarian, who dealt with the origin and history of the Guild and described the chief features of interest in the building and the portraits and exhibits. Tea and light refreshments were subsequently served in the Banqueting-hall.

The present Ironmongers' Hall is believed to be the third which has stood on the site, the first hall having been built somewhere about the year 1457, in the reign of Henry VI. The second hall, which was built during the reign of Elizabeth, in 1587, narrowly escaped destruction by the Great Fire of 1666. It was superseded in 1745 by the present hall, built in the Palladian style, with a vestibule with handsome columns and groined ceiling, and a beautiful banqueting-hall, which for general effect is not surpassed by any similar chamber in the city of London. The plate of the Company includes several specimens of interest, dating from the fifteenth and sixteenth centuries, and the library possesses a fine edition of the "Compleat Angler," by Izaak Walton, a former warden of the guild, whose portrait hangs in the banqueting-hall.

The Company, of the origin of which there is unfortunately no record, is one of the twelve "greater" Livery Companies (there are altogether seventy-nine guilds in the city), and was probably a development of one of the many religious fraternities which flourished in the early Middle Ages before any of the charters or civic ordinances were granted. The first charter was given to the Company by Edward IV. in 1403, and in 1463 Edward III. confirmed the rights conferred upon the Company. The Company, which was frequently subjected to fines and other exactions on the part of the rulers of the land and other powerful personages, has but little antique plate, but among its treasures are two beautiful fifteenth-century "mazers" or maple-wood drinking vessels, silver mounted, of a kind of which only fifty examples are known to be in existence. The bulk of the plate is eighteenth century and later. The banqueting-room, in which the reception was held, is 70 feet long and 29 feet wide, and has a panelled dado 8 feet high, bearing the arms in proper colours of the Past Masters of the Company from 1351. Among other oil paintings of eminent "Ironmongers" of the past which adorn the walls is one of Lord Hood, by Gainsborough, and one of Sir Robert Geffrey, who bequeathed to the Company funds to purchase land for the erection of almshouses.

#### VISIT TO ARMOURERS' AND BRASIERS' HALL, COLEMAN STREET, E.C.

About fifty members and ladies visited the Hall of the Worshipful Company of Armourers and Brasiers on the afternoon of Tuesday, September 28, by invitation of the Court of the Company. The party assembled at the St. Ermin's Hotel, under the guidance of Mr. Harold Jeans and Mr. R. E. Commans, members of the Reception Committee, who accompanied them to the St. James's Park Station of the District Railway to Moorgate Street, whence they proceeded to Coleman Street, where the Hall is situated. The members on their arrival were received in

the Drawing-room by the Master (Mr. George Wood), the Upper Warden (Mr. Sydney Pitt), the Renter Warden (Mr. Arthur Hill), and two Past Masters (Mr. Charles C. Graham and Mr. David A. Bumsted). After a few words of welcome from the Master, Mr. D. A. Bumsted read a short paper dealing with the history of the Company and other matters of interest. After inspecting the pictures and other objects in the Drawing-room, which included some fine specimens of metal work, for which prizes were awarded at exhibitions held by the Company some years ago, the members were conducted into the Livery Hall, where various pieces of ancient plate, comprising loving cups, a mazer bowl, seal-top spoons, &c., were shown to them, and their principal features explained by the Master and Wardens. The ancient plate included the well-known "Richmond Cup," which was presented to the Company in 1557 by John Richmond, Master in 1547-48. The attention of the visitors was also directed to the numerous pieces of armour hanging upon the walls of the Livery Hall, including a valuable tilting suit, formerly the property of Sir Henry Lee, who was appointed to the office of Master of the Armoury to Queen Elizabeth in 1580, and was an ancestor of the present Viscount Dillon, Curator of Tower Armouries, and an honorary member of the Company. In the Court-room were seen a number of deeds relating to the Company's properties of ancient date and a portrait of Roger Tyndall, who was Master of the Company on three occasions, namely, in 1559, 1567, and 1577, and one of Queen Elizabeth's Gentlemen-at-Arms.

At the conclusion of the visit the party was entertained at tea in the Court Dining-room of the Company, and before the visitors left a cordial vote of thanks to the Master and Wardens for their kind reception was unanimously passed by Mr. R. E. Commans.

The Hall of the Armourers' Company (known as "The Brethren of the Craft or Mystery of Armourers") was acquired in the seventh year of the reign of Henry VI., A.D. 1428, and comprised "The Dragon" and five shops in Coleman Street. The Hall escaped the Great Fire of London in 1666, and subsequently in 1750-77 (additional property having been purchased in London Wall abutting upon the Hall) the premises were much enlarged. The amalgamation of the Brasiers' Guild with the Company of Armourers took place in 1708, the names of the Masters since that date being recorded on the panelling of the Livery Hall. The entire premises were taken down and rebuilt in their present form in 1839-41; but most of the internal arrangements, including the Livery Hall with its adornments and decorative features, were remodelled in 1872, and the paintings and many interesting specimens of the armourers' craft were rearranged as we now see them. The names of the benefactors from the time of Eborard Frere, Master of the Company, 1454 and 1455, were also recorded on decorative shields in the main cornice. The principal objects worthy of special notice are the engraved suit of armour, on a bracket on the right of the chair, worn by Sir Henry Lee, Master of the Armoury, to which reference has already been made, a portrait of George I., by Vandrebanks, a painting representing fine pieces of armour, with assumed portraits of the Earl of Essex and General Monk; Northcote's largest work, representing the entry of Bolingbroke into London prior to his coronation as Henry IV. ("King Richard II.," Act V. Scene 2), the arms of Edward VI. in the wood panel of the chimney-piece, and those of William and Mary in the bronze plaque of the buffet. In the Court Dining-room the grant of arms to the Company in the reign of Philip and Mary, 1556, is worthy of notice, especially on account of the sovereign titles accorded to this ill-starred couple. More interesting, perhaps, are the full-length portraits in the Drawing-room of George II. and Queen Caroline by Shackleton, the Court painter of his time. They



are replicas of the state portraits in the National Portrait Gallery. In the same room are two celebrated English pictures, purchased by the Company at the sale of the Boydell Shakesperian collection in 1805. Both these works, as well as the Northcote picture already mentioned, which was purchased at the same time, have been engraved. On the walls may be seen a few notable specimens of blades and other weapons, as well as the processional axes of the mediæval Electors of Saxony, as Masters of the Mining Guild; and in the case at the end of the room are a variety of modern specimens of the brasiers' and metal-workers' crafts, obtained by the Company in 1889, 1890, and 1891, when exhibitions were held in the Hall for the purpose of promoting the brasiers' art, and giving encouragement to apprentices and craftsmen. In the Court-room is a portrait of Roger Tyndale, bequeathed by his will in 1587. As Master of the Company in 1559, 1567, and 1577, and one of Queen Elizabeth's Gentlemen-at-Arms, this picture possesses an historical interest. In the cases on the walls are a few manuscripts worthy of notice. Many of them relate to the conveyances of lands and tenements to the Company in the fourteenth and fifteenth centuries.

#### VISIT TO THE NATIONAL PHYSICAL LABORATORY, BUSHY HOUSE, TEDDINGTON.

Over three hundred members and ladies had signified their intention of participating in the visit to the National Physical Laboratory on the afternoon of Wednesday, September 29, but owing to the inclement weather experienced this number unfortunately shrank to about one-third. A special train conveying the visitors left Waterloo at 2.25 p.m. and Teddington was reached at three o'clock. Mr. Cyrus Braby, member of the Reception Committee, travelled down with the party to Teddington, and acted as guide from the station to the Laboratory, where the visitors were met by Dr. R. T. Glazebrook, F.R.S., the Director of the Laboratory, and Mrs. Glazebrook, and were subsequently conducted, under the guidance of various members of the staff, over the different departments of the Laboratory. The first visit paid was to the thermometric laboratory. Dr. Harker explained the use and application of the instruments and apparatus installed in his department. In the electrotechnical division, which was next visited, Mr. Paterson and Mr. Melsom showed the members the instruments and equipment for the testing of all types of electrical instruments for photometry, while Dr. Stanton, assisted by Mr. Jakeman, showed the visitors over the Engineering Department where the testing of materials of construction is carried out and where impact tests and gauge testing are performed. Subsequently the Department of Metallurgy and of Metallurgical Chemistry was shown to the members. This department, which is under the charge of Dr. Rosenhain, and occupies rooms in Bushy House, together with a new building specially erected, deals with metallurgical research and the investigation of alloys, and with chemical analyses of railway and other material, metals and alloys. Dr. Rosenhain was accompanied by Mr. Murdock and the staff of the department. On the conclusion of the tour of inspection tea was served in the electrotechnical building and in Bushy House, and the main body of visitors returned by special train from Teddington shortly before a quarter past five. A few members, however, remained to make a more detailed inspection of the engineering and metallurgical departments, which were specially kept open for visitors until half-past five.

The work of the National Physical Laboratory at Teddington is organised

in three main departments—the Physics Department, the Engineering Department, and the Department of Metallurgy and Metallurgical Chemistry. The Physics Department comprises divisions for thermometry, optics, electrical standards, general electrical measurements, electrotechnics, photometry, and metrology. In each section the work includes research and maintenance of standards, as well as the testing and verification of instruments sent for examination.

The different branches are now housed in five main buildings. In addition to Bushy House itself, there are separate buildings for electrotechnics and photometry, metrology, engineering, and metallurgical chemistry. The Metallurgy Section at present occupies a number of rooms in Bushy House; the equipment includes a complete metallographic outfit, and an apparatus for photomicrography with ultra-violet light, and much important research has been carried out. In the Engineering Department are a number of machines for the testing of materials under repeated stress or repeated impact; other researches are in progress on wind-pressure, on the resistance of plates and models in a uniform current of water, on the tensile strength of long wires at varying temperatures, &c. High temperature research and the testing of pyrometers is carried out in the Thermometry Division and in the Metrology Building, where the standards of length are kept, a long gallery for the testing of surveying tapes on the flat or in catenary is a feature of special interest.

In addition to the work done at Teddington, the Observatory Department at Richmond (Kew Observatory) carries on meteorological work, as well as the testing of meteorological instruments, thermometers, telescopes, watches, &c. A new Observatory for magnetic work has recently been opened at Eskdalemuir, Dumfriesshire.

#### VISIT TO THE WORKS OF MESSRS. D. NAPIER & SON, LTD., ACTON.

Under highly unfavourable climatic conditions nearly a hundred members and ladies assembled at 1.20 P.M. in the courtyard of St. Ermin's Hotel, previous to being taken to visit the Motor Car Works of Messrs. D. Napier and Son, Ltd., at Acton. Mr. J. F. Melling, member of the Reception Committee, and Mr. W. F. Cheesewright, acted as stewards for the party, for the conveyance of which a number of commodious private motor cars had been chartered by the Reception Committee. The works of Messrs. Napier & Son were reached shortly after 2 P.M., and the visitors were met by Mr. W. F. Rainforth, the General Manager, on behalf of the Company, and conducted over the workshop. At the conclusion of the visit the party was driven from Acton to visit the Mitchell Motor Works and Garage in Soho.

The work carried on at Messrs. Napier & Son's works is chiefly confined to the manufacture of motor cars, and, although the firm is very old established, the introduction of this class of work has necessitated many alterations to the plant and the system of organisation.

The workshops consist of two main buildings, namely, the machine shop and the fitting shop. In addition to these there are the foundry, the smithy, the engine-testing shop, and the road-testing department, together with small outbuildings.

*The Machine Shop.*—This is a single floor building, with a floor area of approximately 6000 square yards, with saw-tooth roofs. The machines are principally semi-automatic, and in the machine shop proper are arranged in sections, similar machines being placed together as far as possible. The sections include those where the operations of boring, drilling, milling,

turning, and grinding are carried on, and among the machines will be noticed many special ones with fixtures for several operations. The machines are driven from line shafting by means of electric motors, which are placed in the roof in order to save floor space.

The rough stores, where the raw material is received, forms part of the machine shop, and in addition to keeping the stock of raw material, is fitted with power-driven saws for cutting off the material before it is issued to the machine shop.

The view-room, or gauging department, is partitioned off from the machine shop at one end of the main bay; and at the other end is the tool-room, which is fitted with a complete range of machines, and is used for the production of special devices such as jigs, tools, &c., for use on the other machines, and by means of which all parts are made to gauge.

*The Fitting Shop.*—This, again, is a single-floor building, with a floor area of 4400 square yards, and contains the departments in which the engines, gear-boxes, rear axles, and the complete chassis are erected. In addition to these departments, the fitting shop contains the finished stores, partitioned off at one end, which contains a stock of finished parts. The material is delivered from the view-room after it is gauged to the finished stores, and from there it is issued to the various erecting departments.

The fitting shop also contains the machines necessary for cutting spur and bevel gears, also hobbing machines, machines for cutting spiral gears, Brown & Sharp machines, and bevel-planing machines.

The cars in course of construction can be seen in all the various stages of completion.

The payment for the work in the shops is based on the bonus or premium system. The clerical work is performed in the bonus office, which occupies one corner of the machine shop, and above which is situated a drawing-office for the design of special fixtures, jigs, &c.

The engine-testing shop and the road-testing department are both of interest, and the apparatus in the fitting shop for the testing of gear-boxes and rear axles is worth inspecting.

### VISIT TO THE MITCHELL MOTOR WORKS AND GARAGE, SOHO.

The bulk of the party which had visited the Works of Messrs. D. Napier & Son proceeded, by means of the special vehicles provided, from Acton to Soho, where they had been invited to visit the Mitchell Motor Works and Garage, Wardour Street. The visitors were received by Mr. John Mitchell, Mr. David Mitchell, and Mr. J. B. Mitchell, Directors of the Company, and entertained to tea and light refreshments, each of the members being presented by the company with a cloth-bound copy of the firm's useful publication, "Motor Roads to London," which gives the itinerary and distances from the metropolis of all the chief towns of Great Britain. Mr. Edgar J. Windsor Richards proposed a hearty vote of thanks to Messrs. Mitchell for their kindness in receiving the party, after which an inspection was made of the fitting and repair shops connected with the garage, and the visitors subsequently left shortly after 5.30 p.m., motor cars being hospitably provided by the firm to convey the members back to their respective destinations.

The garage is a remarkable establishment by reason of its relative size and situation. Erected within a stone's-throw of the most expensive part of the West End of London, it contains over 70,000 feet of superficial area devoted entirely to industrial purposes. It affords ample accommodation for 500 cars,

each accessible for immediate departure, in addition to which there are a large number of separate storage compartments for vehicles deposited for safe-keeping. By means of the large amount of free floor space and the electric lift, any vehicle can be brought from the remotest part of the establishment to either of the exits within a few minutes.

The workshops are fully equipped with modern machinery and appliances for the manufacture of motor-car parts, and any piece of mechanism can be duplicated by the automatic machine tools, which have been carefully selected for their respective work. The machines, which are all driven by electricity, include bevel gear automatic planers and spur gear milling machines of the latest type, automatic turret lathes, besides a full complement of high-speed lathes of various sizes. This installation, adequate as it is for the entire manufacture and equipment of complete vehicles, is now fully occupied in the execution of repairs and replacements, and in view of the great increase of this department a further extension of the workshops is now under consideration by the Directors.

Risk of danger to persons and property has been reduced to a minimum by the precautions taken in the erection and equipment of these Works, and hygienic conditions have been also well considered. The whole structure is fireproof, and there is no corner to which abundant natural light and air does not obtain access.

An interesting department is that which deals with the hiring of cars, and all possible requirements in this connection are adequately provided for. Drivers and mechanics are retained speaking all European and many Asiatic languages, the department numbering among its patrons many distinguished foreign visitors, including some from India, Persia, and the Far East. A large business is that of conveying American tourists to places of interest in the United Kingdom, and for the convenience of these clients the department prepares special routes with time-tables to suit long or short tours, embracing only such places as are likely to interest the persons particularly concerned.

### VISIT TO LAMBETH PALACE.

Despite a heavy fall of rain, a very large party assembled on the afternoon of Wednesday, September 29th, to visit Lambeth Palace and the Royal Doulton Potteries. Motor omnibuses had been chartered to convey the members from the St. Ermin's Hotel, which was the point of assembly, but owing to the impossibility of the outside seats being utilised the accommodation proved somewhat inadequate, and several journeys had to be made in order to convey the three hundred persons who participated in this visit. On the arrival at the Palace the party assembled in the Library, which in earlier times formed the banqueting-hall, and it was here met by the Archbishop of Canterbury, who, together with Mrs. Davidson, welcomed the visitors in a short address which was highly appreciated by those present. Sir Hugh Bell, Bart., President, who with Lord Airedale, Past-President, formed one of the party, replied suitably to the address and thanked the Archbishop for his hospitality in receiving them. Subsequently a tour was made under the guidance of the Archbishop's Secretary (Mr. Arthur Sheppard) and several members of the Archiepiscopal household, the Chapel, Crypt, and so-called Lollards' Tower being visited. One of the groups enjoyed the advantage of having with them Mrs. Davidson herself, who communicated to the party many details of interest concerning the history and associations of the Palace, the occasion forming by common consent of those present one of the most interesting and enjoy-

able fixtures for the week. Before leaving, the visitors were entertained at tea in an apartment adjoining the Crypt.

Lambeth Palace is built on the site of the original Lambeth Manor granted to the Bishop and Convent of Rochester by the Countess Goda, sister of Edward the Confessor, but it is doubtful whether even the oldest portions now contain any vestige of architectural work prior to the beginning of the thirteenth century. The Great Gateway, consisting of two immense square towers, in the upper chambers of which were places of detention for those who had exhibited unorthodox tendencies, was erected in 1490 by Cardinal Archbishop Morton, and fifty years later Cranmer is said to have built the small tower on the north-east of the Chapel. Lambeth House—by which name the Palace was known during its earlier history—suffered severely in the time of the Commonwealth, and on the Restoration, Archbishop Juxon found the residence of his predecessors a heap of ruins.

The Great Hall was formerly the Banqueting-hall, and in the times of Cranmer, and later on of Cardinal Pole, was the scene of many a stately banquet. It was converted to its present use as a library by Archbishop Howley in 1854. It contains a collection founded by Archbishop Bancroft, and now amounting to thirty thousand printed books and fourteen thousand manuscripts, including the *Codices Lambethiani* and valuable collections of Eastern Codices, numerous psalters, missals, martyrologies, biblical and historical manuscripts, Papal Bulls, Royal Letters, and State Papers. Amongst the latter are Lord Burghley's papers, a volume of documents belonging to Archbishop Laud, and the correspondence of Anthony Bacon. The early printed books include ten productions of Caxton's press, and there are also collections of printed Bibles and works on Kentish topography and Diocesan history. Its greatest treasure is, however, a MS. volume of the four Gospels in Latin, known as the Gospels of Mac-Duran, highly enriched by paintings and ornaments typical of early Celtic art. This ancient volume was presented by King Athelstan to the city of Canterbury, and dates from the ninth century.

Probably, however, the most interesting portion of the Palace is the Water Tower, now known as the Lollards' Tower, through its having been the alleged scene of the persecutions of the Lollards, although there is no warranty for the belief that it was ever associated with this sect, the confusion having arisen from the fact that there was actually a Lollards' Tower at "London House," adjoining old St. Paul's. Notwithstanding this, however, the Water Tower possesses an interesting history of its own, and traces of the steps by which the ill-fated Anne Boleyn passed to and from the Chapel, in which sentence of divorce was passed upon her, still remain.

### VISIT TO THE ROYAL DOULTON POTTERIES.

A large proportion of those who participated in the visit to Lambeth Palace also visited the Royal Doulton Potteries, situated about a hundred yards further along the Embankment. Relays of the visitors were brought from the Palace gates by the motor omnibuses in attendance, whilst others who made the Potteries their first objective were similarly conveyed thence to the Palace. At the Potteries the party was on its arrival divided into groups, which were conducted through the studios in which Doulton ware and "Lambeth Faience" wares were being decorated in characteristic manner by the artists and their assistants.

In some instances it was pointed out that the vases were remarkable

from the fact that only one pair of each design was being made. There is still among artistic people a desire to possess articles that are unique.

But for the most part many hundreds of each design were being produced. Even our old friend the Toby Jug was found to be as great a favourite as ever, judging by the number seen in various stages of manufacture.

Mr. Tinworth was engaged on some of the terra-cotta scripture panels for which he is famed the world over. The largest in his studio was 7 feet long, and many of the earlier examples of his work illustrating various biblical scenes embellish the cathedrals and churches of our land.

The fascinating art of the potter "throwing" on his wheel was next shown. Grasping a lump of soft clay, the skilful worker threw it down on a revolving horizontal disc. With nothing besides but a little water and the dexterous use of his fingers, articles of all sorts of shapes appeared in rapid succession. Dozens of these men were busily engaged, some in making teapots, jugs, ink-bottles, and foot-warmers, others in creating huge vessels to condense or store strong acids.

In another part of the works, sinks, traps, stoves, and architectural blocks were being moulded. With the increasing use of steel frames for buildings, the manufacture of ceramic ware for exteriors, especially that which imitates Carrara marble, has received a decided impetus.

Two or three kilns were inspected. It was a revelation to some of the members to watch the packing of tier upon tier of clay ware until the crown was reached. Here could be seen a costly vase side by side with a drain-pipe, or a flower-bowl associating with a condensing worm. The information was imparted that it takes at least a week to burn pottery by the methods practised at Lambeth.

Those who were interested wandered through the various showrooms, containing examples not only of pottery made at Messrs. Doulton's Lambeth and Staffordshire Works, but of metal sanitary fittings produced entirely at their Paisley factory. Enamelled baths, geysers, cisterns, and every sanitary appliance needed in the house, the hotel, and the hospital could be seen, as well as specimens of the plumbago crucibles for which Lambeth is justly noted. After completing the inspection of the various showrooms, the party reassembled at the main entrance, where they were entertained by the company to tea and light refreshments.

The Lambeth works of the Royal Doulton Potteries had their modest commencement in 1815, when Mr. John Doulton, sen., in conjunction with Mr. J. Watts, established a small pottery in Vauxhall Walk. They removed in 1826 to High Street, Lambeth, taking over the single kiln, which till then had belonged to a Mr. Willats. For many years only ordinary stoneware for household and chemical purposes was made, but towards the middle of the century an important step was taken with the introduction of stoneware for sanitary purposes. Factories were built at Lambeth, St. Helens, Rowley Regis, and Smethwick for the manufacture of drain-pipes, gullies, and all the heavier kinds of apparatus. Terra-cotta garden vases and ornamental chimney-pots were shown by the firm at the Exhibition of 1851, and not long after led to the definite development of terra-cotta and glazed wares for architectural purposes.

The factory first erected for this side of the manufacture has been superseded by the handsome buildings on the Albert Embankment, the tall chimney-shaft of which is such a conspicuous landmark. Among the developments at Lambeth may be mentioned the manufacture of crucibles and fireclay wares; fireplaces, mantelpieces, and stoves in glazed ware; filters of all kinds; stoneware conduits and insulators for electric mains;

fitted sanitary goods, and metal work of all kinds for sanitary purposes. Sanitary engineering in all its branches is now an important part of the firm's activities, their new works at Paisley enabling them to handle the largest contracts.

"Doulton ware," as an art product, dates from 1871, although in the 1862 and 1867 Exhibitions a few single pieces of coloured salt-glazed ware had been shown. Encouraged by the success of a small exhibit in 1871, pieces from which had been purchased by the Queen and the South Kensington Museum, the Doulton artists made large displays of the new ware at Vienna in 1873, Philadelphia 1876, and Paris 1878, the Grand Prix awarded in the latter year being repeated in 1889. The Doulton exhibit in 1900 was *hors concours*. Among the many other awards received for the productions of the firm, none gave greater pleasure than the presentation, in 1885, at the Lambeth works by H.R.H. the Prince of Wales, of the Albert Medal of the Society of Arts, "in recognition of the impulse given by Mr. Henry Doulton to the production of artistic pottery in this country."

In 1877 works in Staffordshire were opened for the manufacture of all kinds of china and fine earthenware, and taking these into account, it may be said that practically everything made in pottery is made at one or the other of the Doulton works.

On the death of Sir Henry Doulton in 1897 (he had been knighted in 1887), the business was converted into a limited company, Mr. Henry Lewis Doulton becoming Chairman and Managing Director.

## ROYAL SMALL-ARMS FACTORY, ENFIELD LOCK.

*(By permission of the Army Council.)*

On the afternoon of Wednesday, September 29, the Royal Small-Arms Factory, Enfield Lock, was, by kind permission of the Army Council, open to the members of the Institute.

This factory was established as long ago as 1804, and until 1857 the factory was largely engaged as a small-arms repair department. Before that date the majority of the arms were obtained from the private trade. In 1854 it was determined to establish a factory for the manufacture of small-arms in this country, and £150,000 was voted by the House of Commons for this purpose. This was the first factory in this country where strictly interchangeable articles were manufactured, and though in the process of evolution great progress has naturally been made, the principles remain much the same.

In 1857 the Long Enfield rifle, bore 0·573 inch, velocity 1240 feet per second, was the Service pattern, and it was succeeded by the Snider, bore 0·573 inch, velocity 1240 feet per second. This rifle was then followed by, first, the Martini-Henry, bore 0·45 inch, velocity 1358 feet per second; second, by the Lee-Metford, bore 0·303 inch, velocity 1960 feet per second; third, by the Lee-Enfield long barrel, bore 0·303 inch, velocity 2000 feet per second; fourth, by the present Service arm, namely, Lee-Enfield short, bore 0·303 inch, velocity 2000 feet per second.

The factory is driven by electricity. The power is derived from a central station containing four generator sets, two Parsons steam-turbines, driving shunt-wound dynamos of 250 kilowatts, and two triple expansion vertically enclosed engines driving shunt-wound dynamos of 350 kilowatts capacity. Most of the shops are lit by arc lamps and incandescent electric lamps, but in a few shops high pressure incandescent lamps have been installed.

Complete laboratories for testing the material and ranges for the proof of the guns are contained in the department.

In addition to the current manufacture, all classes of repair work are undertaken, and small-arms from all parts of the world of patterns that have not yet been completely superseded come in for conversion and repair. All the accessories for use with rifles are also manufactured in this factory, viz., swords, bayonets, scabbards, pull-throughs, oil-bottles, and chargers for the cartridges, and are subject to the same rigid inspection that the rifle undergoes. The department is also equipped for the manufacture of Maxim guns.

#### GEAR WORKS OF THE POWER PLANT COMPANY, LTD., WEST DRAYTON.

These works, which, like the Royal Small Arms Factory, were, by the kind permission of the owners, open to members on the afternoon of Wednesday, September 29, are situated on the Great Western Railway main line and the Grand Junction Canal, and have been established four years, for the exclusive manufacture of machine cut double helical gear wheels, to meet the growing demand for this article, which could previously only be obtained from the Continent. The type of gear and manufacturing process are those invented by Mr. Wust, the Company being sole licensees.

The chief feature of these gears is the staggering of the teeth, which in effect halves the pitch, and makes the gear, owing to continuous engagement, particularly suitable for heaviest drives where severe shocks are encountered, and for high velocity work from electric motors and steam-turbines.

The machines on which these gears are cut are extremely ingenious and interesting. Both the shape of tooth and the helix are generated automatically for right-hand and left-hand teeth in one operation, and all sizes of wheels of same pitch are cut by the same tools.

The plant consists of suction gas power installation and three-phase alternating current distribution. The gear-cutting machines are driven by patent multi-speed three-phase motors. Wheels from 1 inch up to 10 feet diameter can be produced, besides complete reduction gears in cases. A plant for making the special cutting tools is also installed. Considerable additions to the plant are at present in progress.

#### VISIT TO MERCERS' HALL, CHEAPSIDE, E.C.

A large party numbering not far short of three hundred assembled on the afternoon of Thursday, September 30, at the St. Ermin's Hotel, Westminster, whence they proceeded from the St. James's Park Station of the District Railway to the Mansion House Station. The party was accompanied by Mr. F. W. Harbord and by Mr. Matthew Murray, members of the Reception Committee, who acted as stewards for the occasion, and the City police again most courteously assisted in conducting the party from the station to Cheapside, where the Mercers' Hall is situated. On their arrival the visitors dispersed to visit the beautiful rooms of the Company, together with the chapel, which was specially opened for the occasion, the fine panelling and carving of which was greatly admired. Subsequently the party assembled in the Court-room, where an interesting address was delivered by the Steward of the Company, who pointed out the various features of interest.



The Hall of the Mercers' Company, the first on the list of the Twelve Great Guilds of London, is in Cheapside, between Ironmonger Lane and Old Jewry. The Mercers were recognised as a Guild in 1172, and incorporated as "The Men of the Mystery of Mercery" in 1393. After the Great Fire, the Hall was rebuilt, in 1672, from the designs of Sir C. Wren. The Company possess a portrait of Dean Colet, founder of St. Paul's School, the management of which he left to the Mercers' Company; a portrait of Sir Thomas Gresham, founder of the Royal Exchange, a member of the Company; and the very fine Leigh Cup of 1499, the oldest and one of the finest pieces of plate in the city. Whittington, the famous "four times Mayor of London," was a member of the Company, and Queen Elizabeth was a "free sister" of the Mercers' Company.

#### VISIT TO THE DOCKYARD AND HIS MAJESTY'S NAVAL ESTABLISHMENTS, PORTSMOUTH.

*(By permission of the Admiralty.)*

The last day of the Autumn Meeting, Friday, October 1, was devoted to a visit to Portsmouth Dockyard and Whale Island, by permission of the Admiralty. The weather was exceedingly fine and an agreeable contrast to the earlier portion of the week, when the rain had considerably detracted from the comfort of the members and ladies accompanying them during the various visits that had been arranged by the Reception Committee. A comfortable special train, consisting entirely of Pullman cars, had been specially chartered for the occasion and over 200 visitors assembled at the Victoria Station of the London, Brighton & South Coast Railway, in order to participate in this excursion. The journey to Portsmouth was performed in two hours, and the special train, drawn by a powerful locomotive most appropriately named "Bessemer," was taken direct through the Harbour Station into the Dockyard, where it drew up on the South Railway Jetty. On their arrival the party, which included Sir Hugh Bell, Bart., President, and Mr. A. T. Tannett-Walker, Vice-President, was met at the Dockyard by Rear-Admiral A. G. Tate, Superintendent, Commander H. W. Simms (representing the department of the Captain of the Dockyard), and members of other departments who had assembled to meet the visitors, who were subsequently divided into two groups, each of which made an extensive tour of the Dockyard and of the repair basins and docks. H.M.S. *Invincible* was thrown open to the inspection of the party, which was further divided for the purpose into smaller groups under the conduct of the naval officers of the vessel, who were indefatigable in their attention to the visitors and in imparting information on the various points of interest. H.M.S. *Invincible*, which is one of the most recent additions to the Navy, is an armoured cruiser of 17,250 tons, carrying eight large guns. She was built by Sir W. G. Armstrong, Whitworth & Co., Ltd., at Elswick, and her registered horse-power is 41,000. She is commissioned for service in the Home Fleet, and is attached to the First Cruiser Squadron. On leaving the *Invincible* the visitors were conducted past the gigantic hull of the *Neptune*, which had only been launched on the previous day, and was lying moored ready for receiving her belt of armour. On the conclusion of the morning's visit the party repaired to the school-room, where luncheon was served. Amongst the guests on this occasion, in addition to the officials previously mentioned, were Engineer Rear-Admiral J. S. Sanders, Mr. J. B. Hunt, Mr. M. E. P. Frost, Mr. E. J. Maginness, and the Mayor and Town Clerk of Portsmouth. On the conclusion of the luncheon, Sir Hugh Bell, Bart.,

President, proposed a hearty vote of thanks to the Admiralty for their hospitality in throwing open the Dockyard to the members of the Iron and Steel Institute, and Commander H. W. Simms replied on behalf of the Admiralty. Sir Hugh Bell next proposed the health of the Mayor and Corporation of Portsmouth, which was suitably acknowledged by the Mayor. The members subsequently proceeded to the King's Stairs, where tenders were awaiting to convey them to Whale Island, where they were received by Captain R. G. O. Tupper, R.N., A.D.C., captain of H.M.S. *Excellent*, the name and rating by which the whole Island is borne in the Admiralty lists. Here the rest of the afternoon was spent in inspecting the gunnery class, and in watching the practice by various classes of gunnery and torpedo parties. The visitors left Whale Island shortly after 4 o'clock, and were reconveyed to the South Railway Jetty, where they joined the special train. The departure for London was made punctually at 5.10 P.M. Tea was served on the train, and Victoria was reached at 7.10 P.M.

#### THE DOCKYARD AND NAVAL ESTABLISHMENTS, PORTSMOUTH.

Portsmouth has been the home of the Navy ever since the days of King John, and the harbour, including as it does the famous anchorage at Spit-head, more amply combines spaciousness with security than any other in the kingdom. The main gate is close to the Hard, and visitors may observe in close proximity therewith the beautiful figure-head of the old H.M.S. *Warrior* on the right. This figure-head, which is carved from solid oak, is typical of the ornamentation lavished on the old oak ships of the past. At this end of the Dockyard are to be found the Boat Store-houses, and extensive stores for masts and spars. The South Railway Jetty affords an excellent view of the harbour and of Gosport, and is commanded at one extremity by the Semaphore Tower, which is used, as its name implies, for signalling purposes, and from which all the vessels in the harbour or the roads can be controlled. Beyond the arch below the Semaphore Tower is the Rigging Loft, in the vicinity of which is a basin, known as the Camber, for small vessels. At the opposite end of the Camber are the King's Stairs, with a spacious range of offices adjoining, occupied by the authorities of the Dockyard. After passing the Boat-house Jetty and the gates which shut off the tidal water from No. 1 Dock, the visitor reaches Pitch House Jetty, and subsequently Docks Nos. 2, 3, 4, and 5, in which small vessels are repaired and fitted for service. Near No. 5 Dock are situated the Block Mills and the Pumping Station, which contains the machinery and pumps used for emptying the small docks. The North Railway Jetty and No. 10 Dock are next in line of route, the Slips, of which there are five, being situated beyond the latter dock. These Slips communicate directly with the harbour, and have served for the launching of some of the largest of the modern battleships of H.M. Navy. The No. 1 Smithy stands to the right of the Slips, and possesses a fine installation of steam-hammers. The Coaling Jetty is close to the "Excellent" Steps, and moored alongside were the steam colliers which serve to transport fuel to the ships. One of the colliers has a capacity of 10,000 tons of coal. The shops in the neighbourhood include No. 3 Smithy, a turnery, a torpedo-tube establishment, and an armour-plate shop. There are also two large basins, one of which, known as No. 2 Steam Basin, has an area of seven acres, while near the large space of ground known as the Extension are to be found a torpedo shop and the new gun-mounting stores, together with the large building recently erected for the manufacture of various descriptions of machinery. This portion of the Dockyard

has an exit known as the Unicorn Gate, which communicates with the town and is close to No. 5 Basin, where are installed two large sheers having a lifting capacity of 100 tons and 80 tons respectively. Adjoining the basin, but farther to the east, are the boiler shops and Docks Nos. 12, 13, 14, and 15, the two last being the largest in the yard. The number of men employed regularly in the Dockyard averages about 11,000. The following are the dimensions of some of the principal docks:—

						Length.	Width.
						Feet.	Feet.
No. 1	Dock	.	.	.	.	228	92½
" 2	"	.	.	.	.	222	89
" 3	"	.	.	.	.	275	91
" 4	"	.	.	.	.	278	85½
" 5	"	.	.	.	.	257	85
" 6	"	.	.	.	.	196	82
" 7	"	.	.	.	.	289	100
" 8	"	.	.	.	.	307	80¾
" 10	"	.	.	.	.	302	100
" 11	"	.	.	.	.	401	99
Deep	"	.	.	.	.	435½	101
No. 12	"	.	.	.	.	496	110
" 13	"	.	.	.	.	560	110
" 14	"	.	.	.	.	560	120
" 15	"	.	.	.	.	611	120

## REPORT ON THE FIFTH CONGRESS OF THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

THE FIFTH CONGRESS of this ASSOCIATION was held at Copenhagen during the first week in September 1909, under the presidency of Mr. Alexander Foss. The previous International Congresses were held at Zurich, Stockholm, Budapest, and Brussels, and reports on these have already been published.\*

In one respect the Conference at Copenhagen was notable on account of the considerably larger attendance of British members as compared with the number who attended at any previous Conference, this being mainly the result of the efforts of the late Mr. Bennett H. Brough in stimulating the interest of British engineers and metallurgists in an Association, the valuable work of which has now come to be recognised throughout the world. The number of British members at the present time is 120, of whom about forty took part in the Congress, and not a few important interests in the country were represented by them. They included :

Mr. W. Dunn (Concrete Institute).  
Mr. F. W. Harbord (Institution of Mining  
and Metallurgy).  
Mr. W. G. Kirkaldy (Concrete Institute).  
Mr. G. C. Lloyd (Iron and Steel Institute).  
Mr. J. T. Milton (Lloyd's Register).  
Mr. George Moores (British Weights and  
Measures Association).  
Mr. G. H. Roberts (War Office).

Dr. W. Rosenhain (National Physical  
Laboratory).  
Mr. E. O. Sachs (British Fire Prevention  
Committee).  
Mr. J. E. Stead, F.R.S. (Iron and Steel In-  
stitute and Society of Chemical Industry).  
Professor R. L. Weighton (Armstrong  
College, Newcastle).

By kind permission of the Engineering Standards Committee, Mr. Leslie S. Robertson, Secretary of the Committee, also attended in a consultative capacity, and gave valuable assistance in the discussions on specifications relating to structural material, pig iron, and wrought-iron pipes.

One or more official delegates to the Congress were appointed by the Governments of the following seventeen countries: The Argentine Republic, the Commonwealth of Australia, Austria, Belgium, Brazil, Chili, China, Denmark, France, Germany, Italy, Hungary, Japan,

\* *Journal of the Iron and Steel Institute*, 1895, No. II. p. 310; 1897, No. II. p. 251  
1901, No. II. p. 321; 1906, No. IV. p. 688.

Holland, Norway, Portugal, Roumania, Spain, Sweden, Switzerland, and the United States. It will be noted that Great Britain does not figure in this list, and at the reception by their Majesties the King and Queen of Denmark immediately before the opening ceremony, as well as during the formal meetings of the Congress, the disadvantage was noticeable of the absence of any official delegate of the British Government. It was also a matter of some regret that, although invitations had been addressed to all the leading educational establishments in this country, the only one represented at Copenhagen was Armstrong College, Newcastle-upon-Tyne.

Amongst the delegates who attended from the United States were Dr. C. B. Dudley (Altoona, Pa.), Dr. R. Moldenke (New York), Mr. W. R. Webster (Philadelphia), Mr. Walter Wood (Philadelphia), and Mr. R. L. Humphrey.

All papers submitted to the Congress were very considerably translated into English, French, and German, the three official languages of the Association. At the Congress meetings it was open to any member to speak in whichever of these languages he preferred, and at the request of any one present who found difficulty in following the speaker there were those at hand who were ready to translate his remarks into one of the other languages. The English-speaking members were indebted to Dr. W. Rosenhain, Mr. Leslie Robertson, Mr. E. O. Sachs, and Mr. G. Lemmy, in particular, for considerable assistance in this respect. A tribute is also due to the remarkable ability with which Mr. E. Reitler, the General Secretary, arranged and organised the business of the meeting, and the facility with which he spoke all the languages of the Congress was of great advantage to the members of the several nationalities present.

The International Testing Association had, at the end of May 1909, a total membership of about 2200 of all nationalities, in addition to which it was supported by about forty-five public authorities, industrial undertakings, and scientific societies. Its objects are—to develop the unification of standard methods of testing, to examine the technically important properties of materials of construction and of other materials of practical value, and to perfect the apparatus used for these purposes. Any person interested in the work of the Association can become a member upon being proposed by two members of the Association. Official bodies and technical societies can be elected direct on sending in an application for membership. The subscription for individual members is at present fixed at 6s. per annum, but the Council of the Association is authorised to increase this when necessary, to cover extraordinary expenses incurred in carrying on the work. Corporate bodies are, however, reasonably expected to subscribe voluntarily a larger amount, and for some years past the Council of the Iron and Steel Institute, in recognition of the importance of the work to British metallurgists, has voted an annual contribution to the funds.

Recently the Association began to publish its transactions in an official periodical entitled "Proceedings of the International Association for Testing Materials," which appears during the year in consecutive numbers, and is distributed gratis to all members. By so doing, how-

ever, a severe strain has been placed upon the financial resources of the Association, and reference was made to this at the Copenhagen Congress, in a resolution by which the Council was authorised to call the attention of governments, scientific institutions, and industrial undertakings to the work of the International Association, and to endeavour to induce them to manifest interest therein by giving financial support.

The Congress was formally opened on Tuesday, September 7th, in the Grand Hall of the University of Copenhagen, by His Royal Highness the Crown Prince of Denmark, Honorary President of the Association, in the presence of their Majesties the King and Queen, the Royal Princesses, and a distinguished gathering. Mr. A. Foss, the President, followed with a short address, in which he thanked their Majesties and the Crown Prince for the interest they had displayed in the affairs of the Association. He pointed out that the value of its work was now becoming more widely recognised, and referred especially to the comparatively numerous attendance of British delegates as evidence of the growing interest displayed by Great Britain therein. The ceremony concluded with a beautiful rendering by the Students' Choir of a cantata of welcome, specially composed for the occasion. Following the purely formal proceedings, Mr. Poul Larsen delivered an address in English on the Danish Cement Industry. That industry, he said, had been mainly built up during the past twenty years, often under most difficult conditions, and without support from the State in the shape of a protective duty. In the year 1888 the total production in Denmark was 115,000 barrels of Portland cement, and the imports 135,000 barrels; while in 1908 the total production was 1,560,000 barrels, of which 1,110,000 were sold in Denmark, and 410,000 barrels exported. The import had decreased to less than 100,000 barrels. The present production of the Danish cement factories was, however, 2,600,000 barrels, or more than twice the consumption of the country. As Denmark possessed no natural resources of water-power or coal, fuel had to be imported, and was at the same time subjected to an import duty. The history of the Danish cement industry was, in fact, largely a report of Danish technical progress.

On the second day, the actual business of the Congress began when the three sections (A) Metals, (B) Cement, Stones, and Concrete, (C) Sundries, met in the Town Hall. The section dealing with metals held its meetings in the Council Chamber of the Town Hall, under the presidency of Mr. O. Busse, Director of the Engineering Department of the Danish State Railways. Honorary Presidents were elected to represent the principal nationalities present at the Congress, Mr. J. E. Stead, F.R.S., being elected Honorary President for Great Britain. The proceedings opened with the presentation of a report by Professor E. Heyn on the progress in metallography since the date of the Brussels Congress in 1906. The main objects of investigation during the three years which had since elapsed had been the following: (1) the establishment of the chemistry of intermetallic compounds; (2) the furthering of the knowledge of the iron-carbon system; (3) the study of special steels and other alloys; (4) the application of metallographic results to actual metallurgical research work; and (5) improvement in metallographic research in its special

bearing upon the testing of materials. The question of the separation of graphite from the iron-carbon system had evoked the most lively interest, and there had been a growing disposition to accept the view according to which the system iron and graphite is regarded as stable, and the white graphite-free iron as metastable. Although no doubt was entertained as to the solubility of graphite in iron, its quantitative determination as fixed by Benedicks did not as yet appear to be quite accurate. Consideration was desirable as to whether in the cementation process one was dealing with the iron-carbon system alone and not rather with the three-component system—namely, iron-carbon-nitrogen, in which other equilibrium relations intervened. A solution of this problem would enable many points to be cleared up which still remained obscure. It was now fully admitted that metallographical research had become an absolutely indispensable adjunct to the testing of materials. In concluding, Professor Heyn paid a tribute to the memory of the late Dr. H. C. Sorby, the founder of the science of metallography.

Dr. W. Rosenhain called attention in another paper to the importance of a closer study of the influence exerted upon the strength and safety of steel by the presence within its mass of "slag enclosures." In view of the importance of the question, the Congress recommended the appointment of a committee to study the whole subject.

*Problem 27.*—Dr. P. Ludwik (Vienna) reported on hardness testing, and pointed out that the cone pressure test was the outcome of efforts to simplify the Brinell test, with the object of making the hardness number independent of the load and of the dimensions of the impression. A direct standard relation between the yield point and tensile strength on the one hand and hardness on the other could not exist, but the recognition of that fact did not exclude the possibility of deducing from the hardness number, with the aid of a coefficient, the yield point and tensile strength with an approximation that would be sufficient for practical purposes. Professors Martens and Heyn described the simplified ball hardness testing machine, and some of the results obtained therewith. A lively discussion then ensued, and the Congress expressed the wish that an investigation of uniform tests of the resistance of materials to mechanical wear be undertaken, and that the results be reported upon in conjunction with the problem of the determination of hardness by ball or cone pressure tests.

*Problem 26.*—G. Charpy, in presenting the official report on impact tests, referred to the rejection by the Brussels Congress of the proposal that the use of tests on notched bars should be generalised, and he now asked that the Congress should define the conditions of a typical method under which comparative tests could be carried out. To utilise the tests in industrial practice it would be sufficient to regard them as a means for the classification of metals, and an endeavour should be made to classify them in groups which would yield analogous results. In order to facilitate the comparison of results of impact bending tests on notched bars, the Congress accordingly recommended the adoption of the following rules, except in such cases where special circumstances might necessitate a departure therefrom :—

1. The notched bar impact test permits the determination of the specific work of rupture or resilience referred to the square centimetre of the notched section.

2. (a) The bars cut have the following dimensions:  $30 \times 30 \times 160$  millimetres. They are notched to a depth of 15 millimetres. The bottom of the notched bar is curved to a radius of 2 millimetres.

(b) For rolled materials such as plates, the bars should have the same thickness as the plate, the surfaces of which are to be preserved. The width of bars to be 30 millimetres. They are notched to a depth of 15 millimetres. The notch is perpendicular to the surface of rolling and the bottom is curved to a radius of 2 millimetres.

(c) For pieces which do not permit the use of bars  $30 \times 30$  millimetres, the section shall be  $10 \times 10$ . They are notched to a depth of 5 millimetres. The bottom of the notch is curved to a radius of  $\frac{3}{4}$  millimetre.

(d) The size of the bars used is always to be recorded.

3. The bars are tested by bending and receive at their centre upon the side opposite to the notch the impact of the drop weight, the knife edge of which is rounded to a radius of 2 millimetres. The bars rest on knife edges spaced 120 millimetres apart in the case of types *a* and *b*, and 40 millimetres apart in the case of type *c*.

4. The rupture of the bar shall be effected by a single blow by means of an apparatus which shall be provided with means for measuring the work absorbed in producing the rupture.

5. The temperature should be as nearly as possible between  $15^{\circ}$  and  $25^{\circ}$  C., and in all cases should be recorded with the results of the tests.

The Congress also recommended that a committee be appointed to collate all the results which would permit the establishment of a connection between the properties manifested under the tests and the behaviour of the pieces in service, and that this committee should also study the various apparatus devised for impact testing, with a view to establishing a basis for their comparison.

James E. Howard (Massachusetts, U.S.A.) presented some results of tests on the endurance of steels under repeated alternate stresses, showing that, as the stresses are increased in magnitude and approach in value to the elastic limit of the steel, a rapid decrease is manifested in the endurance of the material.

Professor F. Schüle and E. Brunner (Zurich) also reported on quality and endurance tests on copper wires.

*Problem 43.*—Professor M. Rudeloff (Gross-Lichterfelde) investigated the influence of increased temperature on the mechanical qualities of metals, for which the Congress expressed their warm thanks. In another contribution on the subject, Professor L. Guillet and L. Revillon (Paris) showed that when the temperature of steel was raised, the resistance to shock, after first increasing up to a temperature of  $200^{\circ}$ , fell to a minimum before increasing again as the steel became red-hot. The



temperature of maximum fragility was always the same and was about 475°.

*Problem 28.*—E. Rasch (Gross-Lichterfelde) reported on a method for determining elastic and critical stresses in materials by means of thermo-electric measurements, the object of the investigation being to find a method which was exempt from arbitrary interpretation, and sufficiently simple and rapid to meet the requirements of technical practice. The determination by thermo-electric measurement of the variations in temperature, which accompany the deformation of the specimen under external stress, appeared to meet these requirements. The Congress agreed to nominate a committee for the purpose of studying the utilisation of the electric and magnetic properties of metals in the testing of material.

*Problem 1.*—Dr. A. Rieppel (Nuremberg) reported further on the introduction of international specifications for iron and steel. The previous report on the results of the work of Committee I., of which Dr. Rieppel was chairman, was presented to the Brussels Congress in 1906. According to this the work had progressed very slowly, because most countries were devoid not only of uniform national specifications for iron and steel, but also of recognised associations for the testing of metal which could suitably take in hand the unifications of the existing specifications. These preliminary requirements were fulfilled only in three countries mainly concerned in the manufacture of iron and steel—namely, Germany, Great Britain, and the United States. It was accordingly determined at the Brussels Congress that a sub-committee consisting of representatives of the three countries named be formed, which should endeavour to establish international specifications on the basis of the German, British, and American standard conditions. The work of that sub-committee was attended with some difficulty, but owing to the efforts of Mr. W. R. Webster (Philadelphia), representing the American Society for Testing Materials, who took the greatest interest in the matter, considerable progress was made at a meeting held in London in July 1909. Dr. Rieppel had forwarded for the consideration of that meeting a most valuable summary, presenting in parallel the principal points of the standard specifications of the above-mentioned three countries for structural iron and steel, and at the urgent request of the sub-committee this summary had been added as an appendix to his report. It was, however, recommended that owing to the apparently insuperable difficulties imposed by the varying conditions prevailing in each country, the question of the adoption of uniform international specifications should be deferred. For the present, therefore, they confined themselves to recommending that copies of the existing specifications should be sent to the standard authorities of the respective countries, in order that when at any future time these associations have under consideration the revision of their own specifications, they might compare them with the corresponding specifications submitted from other countries, and endeavour, wherever possible, to bring them into line with these.

There was a keen discussion upon the report, which brought out the fact that in Russia, Italy, and Belgium the Governments were buyers of

so large a proportion of material that the Government specifications were generally accepted in those countries as standard conditions. In the case of these and other countries which had not submitted to Committee I. authoritative standard specifications, it was agreed that if the representatives of the countries concerned would take the necessary steps towards obtaining such specifications, these should also be taken into consideration by the sub-committee in making their comparison of existing standard conditions. Ultimately it was unanimously decided to approve in general the principles laid down in Dr. Rieppel's report to the Congress, and Committee I. and the sub-committee were invited to continue their valuable labours in co-operation with the national associations, and if possible to lay before the sixth Congress definite proposals as to the basis of international specifications for iron and steel.

Dr. A. Rieppel also presented a report containing a comparative summary of the specifications of Germany and the United States for cast iron and foundry pig iron, prepared with the kind assistance of Mr. Walter Wood (Philadelphia). The Congress unanimously resolved that for the purpose of defining more accurately the quality of pig iron than is possible by the present method of grading by fracture appearance, Committee I. (the sub-committee) be instructed to inquire in the various countries concerned as to how far specifications by analysis may be usefully substituted for the present method of grading by fracture appearance, and that they be authorised to take such steps as they may deem advisable to give effect to this resolution.

*Problem 25.*—Messrs. Sulzer Brothers (Winterthur, Switzerland) presented a report embodying the results of experiments carried out on cast iron bars of various sections for the purpose of determining the strength of cast iron. The tests were made on separately cast bars and on bars taken from actual castings.

Dr. R. Moldenke advocated the adoption of a cast arbitration bar of standard dimensions, and on his recommendation the Congress referred the problem of the study of methods for testing cast iron to Committee I for further consideration.

*Problem 24.*—Professor H. M. Howe (New York) and Professor A. Sauveur (Cambridge, Massachusetts), in a report dealing with the uniform nomenclature of iron and steel, described the progress which had been made since the first report\* was presented to the Brussels Congress in 1906. Since then the committee appointed to deal with this subject had done little more than collect information with a view to future action. The Congress recommended that the committee should continue their work, and that they prepare for the next Congress a revision of their proposals for uniform nomenclature, taking account of the further progress in metallurgy, and of any suggestion which might be received from the national associations for testing materials. The following list of definitions of structural constituents of steel, presented by Professor H. Le Chatelier, was also approved:—

The microscopic constituents of steels may be divided into homo-

\* See *Journal of the Iron and Steel Institute*, 1906, No. IV. p. 699.

geneous chemical constituents, "métalal," and into heterogeneous chemical constituents, the "aggregate." These microscopic constituents are, taking them in the order of their increasing complexity:—

*Ferrite*— $\alpha$ -iron—containing in solution, in the various brands of iron and commercial steel, very low percentages of other elements, and in all cases less than 0.05 of carbon.

*Graphite*, a variety of carbon identical with the graphite of mineralogists, that is to say, characterised by a density of 2.25, and by the property of yielding, under the action of suitable oxidising mixtures, graphitic oxide.

*Cementite*, a definite carbide of iron,  $\text{Fe}_3\text{C}$ , and

*Austenite*, a solid solution of carbon and of iron in the  $\gamma$  state, normally stable above the zone of critical temperatures of the steel. It can, in certain special cases, be maintained in the cold, and is then characterised by the weakness of its magnetic permeability (ferro-nickel and manganese steel).

These first four constituents are chemically homogeneous.

*Pearlite*, the aggregate formed by the eutectoid derived from the normal separation into ferrite and cementite of the austenite cooled to below the zone of the critical temperatures of the steel. It contains on an average about 0.9 per cent. of carbon.

*Martensite*—métalal—is a solid solution of carbon and of iron. It is not normally stable at any temperature, and can only be maintained in this unstable condition at low temperatures. It may be distinguished from austenite, which it closely approximates in composition, by a greater degree of magnetic permeability and of hardness. It can be obtained by cooling the steel from temperatures above those of the critical zone sufficiently rapidly to prevent the separation of the austenite with production of pearlite, but not rapidly enough, however, to maintain the austenite unaltered.

As a perfectly characteristic example of martensite may be instanced eutectoid steel, that is to say, in the vicinity of 0.9 per cent. of carbon quenched at a temperature of  $800^\circ$ , the material being in the form of square bars of 1 square centimetre section in cold water.

*Osmondite*, the homogeneity or heterogeneity of which is still under discussion, is an intermediate state occurring during the reversion of martensite to the pearlitic state which is more stable at ordinary temperatures. It is considered to be a constituent properly so called by reason of the existence of a discontinuity in the variation of certain properties of the metal during its transformation from one extreme state to the other. It is characterised by a maximum solubility in acids, and by a maximum coloration under the influence of acid metallographical reagents. It can be obtained in well-marked form, amongst other methods, by annealing the martensite of the eutectoid steel, that is to say, of steel containing about 0.9 per cent. of carbon, at  $400^\circ$ .

The question of defining troostite and sorbite was, on the suggestion of Mr. J. E. Stead, deferred for consideration by the Council at a later period.

*Problem 38.*—Professor L. Guillet (Paris) reported upon the progress

made in studying the conditions necessary to form the basis of specifications for the purchase of copper. The Congress warmly approved the committee's proposal to extend the scope of their work, and to include in their reference the study of specifications for copper alloys.

A. C. Karsten (Copenhagen) presented a paper on the unification of methods of testing wrought-iron pipes. The author referred to the communication of Professor Hannover to the Brussels Congress, and gave in tabular form the results of a series of tests made in accordance with the standard conditions of the Danish Society of Engineers. An internal pressure test was not included in the series, as earlier experiments had established that all pipes which withstood a bending test were able to bear a much higher internal pressure than the conditions required. He proposed a revised set of conditions for the delivery of wrought-iron pipes for steam gas and water. The Congress referred it to Committee I. for examination, with instructions to bring up a report at the next Congress. It was unanimously agreed, however, that the question of pipe threads should be excluded from the reference to the committee, Mr. Leslie Robertson pointing out that this subject was already under consideration by the Commission recently appointed by the French Society of Gas Engineers.

Dr. W. Exner (Vienna) introduced the subject of the international regulation of technical testing, urging that endeavours should be made to arrive, by means of international agreement, at uniformity of nomenclature and reciprocity in the recognition of results of tests on motors and machine tools in the same manner as was being done in the case of testing material. He recommended the extension of the work of the Association to the whole field of technical testing.

The following is a list of the other papers submitted to Section A, in addition to the official reports:—

- "Special Steels." By L. GUILLET (Paris).
- "The Heat Treatment of Spring Steel." By L. H. FRY (Paris).
- "'Slag Enclosures' in Steel." By W. ROSENHAIN (Teddington).
- "Simplified Ball Hardness Testing Machine and Results obtained therewith." By A. MARTENS and E. HEYN (Gross-Lichterfelde).
- "The Cone-Pressure Test for Determining the Hardness of Permanent Way Materials." By A. GESSNER (Vienna).
- "Investigations on the Brinell Method of Determining Hardness." By H. MOORE (Woolwich Arsenal).
- "Notched Bar Impact Bending Tests." By F. SCHÜLE and E. BRUNNER (Zurich).
- "The Definition of Resilience in Impact Tests." By L. RÉVILLON (Paris).
- "Impact Tensile Tests." By P. BREUIL (Paris).
- "Application of Modern Testing Methods to Copper Alloys." By L. GUILLET and L. RÉVILLON (Paris).
- "Comparative Static and Dynamic Notched-Bar Bending Tests." By A. LÉON and P. LUDWIK (Vienna).
- "Note on the Rupture of Normal Cylindrical Test Samples by Longitudinal Impact." By P. WÉLIKHOW (Moscow).
- "The Utilisation of the Magnetic and Electric Properties of Materials in conducting Mechanical Tests." By A. GRÜNHUT and J. WAHN (Vienna).
- "Ferro-magnetism and the Study of Metals and Alloys." By P. WEISS (Zurich).

- "Method for Determining the Limit of Elastic Strength by Means of Thermo-electric Measurements." By E. RASCH (Gross-Lichterfelde).
- "A New Mirror Apparatus for Measurements of Elasticity." By B. KIRSCH (Vienna).
- "Sparks as Indications of the Different Kinds of Steel." By M. BERGMANN (Budapest).
- "The Principles of 'Technological Mechanics.'" By P. LUDWIK (Vienna).
- "Internal Friction in Loaded Materials." By G. H. GULLIVER (Edinburgh).
- "Irregular Strains due to Nonhomogeneity of Materials." By A. LEON (Vienna).
- "Connection between the Permanent Sets caused by Traction and Compression." By W. MISÁNGYI (Budapest).
- "Tenacity and Malleability." By W. MISÁNGYI (Budapest).

#### SECTION B. (CEMENT, STONES, AND CONCRETE).

This section was presided over by Captain T. Grut, and Mr. E. O. Sachs, the delegate of the British Fire Prevention Committee and the Concrete Institute, was elected Honorary President representing Great Britain. The papers contributed numbered over thirty, and the following are notes of the official reports:—

*Problem 41.*—Professor F. Schüle (Zurich) reported that his committee had drawn up a programme of work, but in view of the immense field of labour which was opened out by the admission of the study of reinforced concrete to its programme, it had become necessary to limit the work, as the most important of the series of investigations was still proceeding. It was thought better to await the results of these before formulating definite conclusions in regard to the numerous problems connected with reinforced concrete. The report was supplemented by valuable appendices describing results of experiments made in Germany by the German committee on reinforced concrete, in Italy by Professor J. Benetti, in Denmark by Professor E. Svensen, in Holland by S. J. Rutgers, and in Switzerland by Professor Schüle. An appendix to the main report was also presented by C. Rabut (Paris) dealing with the measurement of deformation of reinforced concrete structures under service conditions, and another by F. von Emperger (Vienna) on casualties in reinforced concrete structures. A resolution of thanks to the committee was passed, and they were invited to continue their work upon the plan outlined by Professor Schüle. The hope was also expressed that the committee might receive financial support from institutions and authorities interested in the subject.

*Problem 42.*—R. Fèret (Boulogne) reported on the progress made in the methods of testing hydraulic cements. Professor F. Schüle (Zurich) also gave results of uniform tests of hydraulic cements by means of prisms. On behalf of the Hungarian Society for Testing Materials, Dr. C. Zielinski (Budapest) presented a report on the setting of Roman and Portland cement as paste in mortars and concrete. The Congress asked the committee charged with the study of tests on plastic mortars to continue their investigations with due consideration of the results obtained by the Hungarian Committee. It was hoped that they would be able to lay before the next Congress a definite method of using plastic mortars for the testing of cement. The same committee was instructed to investigate the possibility of adopting an international

standard sand, and if not, to procure information showing the comparative value of the different national standard sands.

*Problem 32.*—Mr. Bertram Blount (London) reported on accelerated tests and the constancy of volume of cements. The report contained directions as to the manner in which the Le Chatelier test should be carried out, and an account of the results of the experience with the test in Great Britain, which gave rise to a long and somewhat controversial discussion. Finally the Congress adopted the proposal of the committee, and decided to recommend the method of Le Chatelier as the standard accelerated test for the constancy of volume of cements. The representatives of German manufacturers and consumers, however, opposed the resolution, and formally dissociated themselves from the action taken by the Congress.

*Problem 9.*—Dr. F. Berger (Vienna) reported on rapid methods for determining the strength of hydraulic cements. It appeared that the results of a great number of hot-water tests were so contradictory that the test seemed too untrustworthy to admit of its employment for determining by means of rapid tests the strength of hydraulic cements. The Congress, therefore, did not recommend pursuing further the question of the applicability of such tests. On the other hand, the experiments of L. Deval (Paris), an account of which was given in an appendix to Dr. Berger's report, demonstrated how valuable the hot-water test could prove for the purpose of obtaining information as to the constancy of volume. A further appendix to Dr. Berger's report was presented by A. Greil (Vienna).

*Problem 30.*—Professor M. Gary (Gross-Lichterfelde) reported on the progress made in determining the simplest method for the separation of the finest particles in Portland cement by the liquid and the air process. The paper was supplemented by an appendix prepared by M. Petersen (Copenhagen). The committee was invited to continue their work and report further on the results at the next Congress.

*Problems 11 and 40.*—Reports on testing puzzolanas and gypsum were presented by G. Herfeldt (Andernach), and by Professor M. Gary and R. Fèret, on behalf of the respective committees charged with the study of these subjects; but it was decided to postpone dealing with these questions until the next Congress.

*Problem 31.*—On the question of the effect of sea water on cement, the Congress decided to appoint a committee for the purpose of obtaining any information additional to that contained in the several reports on the subject presented to the Congress. The reference to the committee included the collection of information on the effect of sea water on Portland cement sea structures of more than twenty-five years' standing, and the carrying out of certain tests proposed by E. Leduc (Paris) on the effect of sea water on specially prepared cement.

*Problem 7.*—Professor J. Hirschwald (Berlin) gave an interesting lecture, illustrated by lantern slides, upon the microscopic-petrographic investigation of the weather-resisting capacity of building stones. As the result of this report, and of another by Professor Kloes (Delft), it was agreed to form a committee for the purpose of investigating the

influence of the composition of the mortar and the quality of the building stone on the weather resistance of masonry.

In addition to the reports of the committees, the following papers dealing with cement were also submitted to Section B:—

- "Influence of Repeated Loading upon the Adhesion between Concrete and Iron, of Bright and of Rusty Surfaces." By B. KIRSCH (Vienna).
- "The Influence of Transverse Ties of Small Sections on the Strength of Concrete: System of Free Ties." By W. P. NEKRASSOW (St. Petersburg).
- "Experiments on the Decomposition of Mortars by Sulphate Waters." By J. BIED (Viviers, Ardèche).
- "The Condition of Cement Blocks in some of the Russian Ports in the Black and Caspian Seas." By W. CZARNOMSKI (St. Petersburg).
- "The Use of Reinforced Concrete for Sea Walls." By M. MÖLLER (Brunswick).
- "Cement in Sea Water." By A. POULSEN (Copenhagen).
- "Theory of the Influence of Frost on Natural Stones." By H. SEIPP (Kattowitz).
- "The Determination of the Gelivity of Stones." By E. LEDUC (Paris).
- "The Bonding of Layers of Mortar after different Time Intervals." By B. KIRSCH (Vienna).
- "Notes on Trass, Trass-Cement, and Cement-Lime Mortars." By H. RENEZEDER (Vienna).
- "Contribution to Methods of Investigation of the Elastic Longitudinal Deformation of Concrete." By B. v. BRESZTOWSKY (Budapest).
- "The Results of the Use of Mortar of Improper Composition." By J. A. v. d. KLOES (Delft).
- "The New German Standards for the Uniform Delivery and Testing of Portland Cement." By M. GARY (Gross-Lichterfelde).

### SECTION C.

The third section, dealing with miscellaneous subjects, was held under the presidency of Commodore B. Münter, Mr. J. T. Milton (Lloyd's Register) being elected as Honorary President representing Great Britain.

*Problem 39.*—Dr. M. Albrecht (Hamburg) presented an official report giving outlines of specifications for the supply of oils for technical application.

*Problem 35.*—Mr. E. Camerman (Brussels) reported on methods of testing rubber, remarking that since the Brussels Congress no important alterations had taken place in the methods of testing by chemical analysis. A most comprehensive contribution on the mechanical tests of rubber was presented by P. Breuil (Paris). K. Memmler and A. Schob (Gross-Lichterfelde) also furnished a report upon the same subject.

*Wood.*—Professor W. K. Hatt (Lafayette, Ind., U.S.A.) reported on the present status of timber tests in the Forest Service, United States Department of Agriculture. The results of experience for the past six years were given in Circular 38 (revised), Forest Service, Department of Agriculture, entitled "Instruction to Engineers in Timber Tests." Recently a department of microscopic examination of wood had been added to study the manner of failures in the tissues, and changes in structure resulting from heat treatment. The Congress recommended

the appointment of a committee on wood testing to communicate with the national societies existing in different countries for the purpose of examining the desirability of making wood tests on large pieces instead of limiting the tests to small perfect pieces.

*Problem 18.*—Professors E. Heyn and O. Bauer (Gross-Lichterfelde) presented a paper on the corrosion of iron in water and aqueous solutions, in which they showed, with regard to the generally accepted theory as to the protective effect of sodium carbonide, that this did not afford absolutely effective protection. A résumé of tests carried out in the United States in connection with preservative coatings for iron and steel was presented by S. S. Voorhees (Washington). J. Cruickshank Smith (London), in another paper, proposed the investigation of protective coatings for metals on international lines, but it was felt that it was too great a task for the Association to include this matter in its sphere of operations. E. Camerman (Brussels) discussed the most suitable composition of protective paints. The process of galvanisation as a medium for the protection of iron was discussed, and as this was a matter upon which no report was submitted, the Congress expressed the hope that research might be made as to the results of galvanising or coating with tin. It was also considered highly desirable that an investigation be made as to the best methods of keeping clean the bottoms of iron and steel ships.

*Paper.*—Professor A. Retjö (Budapest) gave an interesting account of continually repeated tests on paper. The resistance of paper to repeated bending and folding had hitherto been determined by hand treatment, but it was now ascertained by the aid of the Schopper folding apparatus.

On Saturday, September 11, the Congress, having assembled in general meeting, concluded with a lecture, before a large and deeply interested audience, by Mr. J. E. Stead, F.R.S., entitled:—

#### MICROSCOPY AND MACROSCOPY IN THE WORKSHOP AND FOUNDRY.

After a brief reference to the death of Dr. Sorby, the pioneer of metallography, through which the whole scientific world had sustained a severe loss, Mr. Stead presented the views expressed by a number of British manufacturers on the value of the microscope in investigating metals.

In some copper and brass factories the microscope had proved invaluable. Mr. Tomlinson, manager of the Broughton Copper Company, wrote that indirectly it was useful, because one could with its aid detect in metals certain ill effects caused, for instance, by overheating, and this damage might be traced to some prior annealing or other heating operation. Cases often arose when the expense and time taken by a chemical analysis had been saved, as the microscope afforded a rapid means of deciding approximately the composition of metals and alloys. The Royal Gun and Carriage Factories, Woolwich, reported that the microscopic examination of brass was a matter of daily routine. The Consett



Iron Company, Ltd., stated that the microscope was regularly used in all cases where ordinary analysis failed to yield satisfactory explanation and more extended research was necessary. According to the report of the Wigan Coal and Iron Company, Ltd., the microscope was regarded in their works as a necessary adjunct to the chemical and metallurgical work in the laboratory. In the Crewe shops of the London and North-Western Railway it was said that it would appear from microscopical investigations that it was possible to discover the qualities of metals even better than by either mechanical tests or chemical analysis, within certain limits. Messrs. Thomas Firth & Sons, Ltd., expressed the opinion that before practical everyday use could be made of the microscope, the meaning of the terms and the reactions of the substances they represented must be learned by practical experiment and observation. Messrs. D. Colville & Sons, Ltd., reported that they found the microscope of very great assistance in everyday work. Messrs. Vickers, Sons & Maxim, Ltd., stated that the microscope was in constant use in connection with the heat treatment of the various alloy steels used in gun and armour-plate manufacture, &c. It had been found to be most useful both as a guide indicating correct heat treatment and as a means of ascertaining whether the treatment ordered had actually been carried out. A metallurgical investigation laboratory had been in active operation for some years at the Sheffield works of the company, and in it the microscope had been very extensively used in researches bearing upon the special classes of steel whose manufacture had presented difficulties.

Messrs. Cammell, Laird & Co., Ltd., wrote that if a casting was to be subjected to subsequent costly machining, or complicated heat treatment, a preliminary micro-examination was sometimes found useful, although even in those cases the examination of a large etched section by means of the hand magnifier was usually more successful. In the great majority of cases the microscope was employed, not to discover defects, but to investigate the origin and determine the particular stage at which they were produced. For the latter purpose microscopic methods were absolutely indispensable.

Those were typical examples of replies received from British manufacturers. There were few large industrial works where microscopic examination was not regarded as essential, and if works had not microscopic equipment they obtained outside professional assistance. In every college and technical institution in Great Britain where metallurgy was taught, students were instructed how to use the microscope for the purpose of obtaining knowledge of the structure of metals and alloys.

He had obtained from many well-known investigators of European and American fame who were interested in the application of the microscope information of which the following was a brief summary:—

In regard to France, Mr. P. Pellin had furnished a list of manufactories, numbering seventy, in which the microscope had been found to be an adjunct to more efficient practice. Professor Le Chatelier, whose admirable microscope was used throughout France, stated that considerable installations were in use at the works of De Dion-Bouton, under the

management of Professor Guillet; at the works of Saint Jacques at Montluçon, the director of which is Mr. Charpy; and at the steelworks at Creusot, under the management of Mr. Harmet.

Dr. Carl Benedicks stated that in Sweden, up to the present time, the microscope had been mainly used in connection with tool and special steels. Metallography, as a routine science, had not been employed to a great extent. Captain N. Beraieff communicated some very interesting information as to the use of the microscope for very many years by Anossoff, and later by Tschernoff, Rjechofarsky, and at many of the steelworks in Russia.

In Belgium, at the works of the Société Anonyme Fabrique Nationale d'Armes de Guerre and Société Anonyme des Ateliers Germain, the microscope was in regular use. At the first-named works, the Le Chatelier microscope had been an indispensable necessity in the examination of all polishable metals, although for industrial purposes its use could only be said to be limited. La Société des Ateliers Germain reported that the microscope was of special service for the discovery of causes leading to fracture of metals used in motor car construction. In Spain, at the Trubia Gun Factory, the microscope was extensively applied to practical purposes for the examination of ordinary and special steels, alloys, brass, bronzes, &c. It was interesting to note that it had been suggested that in every test of brass for cartridges the micrographical investigations should be adopted.

In America, Mr. Albert Sauveur stated that he had information of the use of the microscope in 134 large industrial concerns, 92 of which were steelworks, 16 non-ferrous metallurgical plants, and 26 miscellaneous industries or concerns, such as railroad companies, &c. The application of the microscope was taught in twenty-eight technical institutions. On the authority of Dr. Wüst very many works in Germany and other countries used the microscope as an aid to their work.

The method of auto-sulphur printing, first discovered by Professor Heyn and applied by him and by his assistant, Professor Bauer, and afterwards modified by Professor Baumann, was, if properly applied, most useful in foundry practice. This method had been more usually applied to the detection of local and axial segregation of sulphur in steel, but it was capable of showing approximately the amount of sulphur in cast iron. As phosphorus in cast iron existed in isolated masses of phospho-iron eutectic, and as the amount of these masses bore a close relation to the percentage of phosphorus present in pig iron, an approximate estimate of the element actually presented might be made by examining polished and etched sections of grey pig irons. It was well known that the amount of combined carbon in steels could be estimated with a fair degree of accuracy by microscopic examination; it was almost as easy to estimate the amount of combined carbon in grey cast iron or in grey pig irons. The importance of this fact to the foundry foreman was very great.

The macro- and micro-structure of steel castings were of great importance to the steel-founder. He could readily locate segregations, and determine whether the sulphur was relatively high or low by the auto-sulphur print-

ing process. He could check the work done in the annealing furnace, and determine by the examination of pieces cut out from the casting whether the annealing temperature had been too high or too low, and whether or not the castings had been annealed.

In foundry practice, where the facings of the moulds consisted of a graphitic mixture, the outer envelope of the steel in contact with the mould itself was usually higher in carbon than the mass of the metal. When the annealing had been properly done, the envelope was completely decarburised, and the castings sheathed in a thin covering of carbonless iron or ferrite. This decarburised layer varied in thickness with the time and temperature, and with the percentage of carbon in the steel. In steels containing about 0.30 per cent. to 0.35 per cent. carbon, it was sometimes only 0.05 millimetre in thickness when the castings were small, and as much as 1 millimetre in large castings. In unannealed steels the ferrite envelope was almost invariably absent. The altered microstructure of the mass of steel produced by annealing, as compared with the "casting structure," was usually sufficient to enable one to say whether the steel had been annealed, but not if the temperature of annealing had been excessive, and it was in such cases that the decarburised envelope had to be looked for. A thick ferrite envelope and a coarse triangular structure of the pearlite in the steel itself were indicative of annealing at excessive temperatures. The presence of granular pearlite indicated clear evidence of prolonged annealing at temperatures between 750° C. and 650° C., and steel in this condition was usually very soft. When the annealing was done by heating to between 850° and 900° C., and the steel was removed from the furnace and cooled in the air, the pearlite was nearly always of the lamellar variety.

It was now a common practice to improve the surfaces of defective steel castings by electrically melting and filling blowholes with iron or steel. It was recognised in important work that the castings should be annealed after electric welding. Etching with 20 per cent. nitric acid after rough polishing would show at once whether electrically welded steel had been annealed or not, for, if not, the steel surrounding the weld always consisted of either martensite, troostite, or sorbite, and each of these gave a dark stain on application of the strong reagent, whilst the iron melted electrically and used to fill the cavities was always in the form of ferrite, and remained white after etching.

This etching method was, therefore, most valuable, for it enabled the works inspector or engineer to determine on the finished work the areas welded, and whether or not the steel had been annealed after welding. Annealing not only changed the troostite, &c., into pearlite, but removed the strains set up by the excessive local heating.

In the manufacture of malleable castings, the microscope was useful in determining to what extent decarburisation had taken place, and whether there was anything abnormal in the structure of the metal. There were no better means of controlling the workmen who were responsible for the proper case-hardening of iron and steel than by the use of the microscope. Sections of case-hardened material after polishing and etching indicated with certainty the depth to which the carbon had penetrated the metal.

Many so-called mysterious failures of boiler and other structures had been explained by the use of the microscope. In most of them fracture had been proved to have been initiated by maltreatment of the steel when cold. The steel had been found to be crushed, the ferrite grains flattened, and the metal made most tender. In four cases at least of boiler failure maltreatment had proved to have been the cause. The auto-sulphur prints obtained from sections of steel billets enabled the manufacturer readily to detect serious segregation, and the same method could be used for detecting segregation in wire rods and even in the finished wire.

The microscopic examination of wires also was useful, and particularly so in the case of wires and wire ropes which had failed during use and in the course of manufacture. It had been noticed that wires which contained definite proportions of fine micro strings of foreign matters, such as cinder-oxides, or sulphide of manganese, were incapable of standing the torsion test, and sometimes broke up during the pickling process after the wire rods had been patented or "tempered."

The microscope was also useful in ascertaining whether or not the rods had been evenly tempered. It occasionally happened that in patenting high carbon rods (0.75 per cent. to 0.95 per cent. of carbon) portions of the steel actually contained free martensite, or, as some called it, hardenite, and when martensite was present "drawing" was impossible. On polishing longitudinal sections and etching with picric acid in alcohol or other suitable reagent, the martensite remained white on a ground mass of troostite and sorbite.

Sometimes during use, wire ropes employed for winding and for cable tram lines were subjected to violent friction sufficient to heat the crowns of the wires to above the recalescence point, and this, followed by chilling, left the surface skin intensely hard. An examination under the microscope of wire so affected, after suitable etching, revealed the presence of martensite. When the brittle skin was formed, and the rope passed over a pulley in such a way as to produce considerable flexure, the hardened skin cracked, and the cracks once formed travelled through the wires, which then broke up, and the rope became useless for further work and had to be replaced.

The lecture was beautifully illustrated by a number of lantern slides, and a hearty vote of thanks was accorded to Mr. Stead, who at the close presented his workshop microscope to Professor Hannover, Director of the Royal Government Testing Laboratory, Copenhagen.

In concluding the business of the Congress, the President, Mr. Alexander Foss, referred briefly to the changes which had taken place in the constitution of the Council of the Association since the last Congress, and the loss sustained through the death of Mr. Bennett H. Brough. He then announced that the Council had resolved to elect as the new President Dr. Charles B. Dudley, President of the American Association for Testing Materials. Dr. Dudley had presented, on behalf of that Society, an invitation to hold the sixth Congress in the United States in the autumn of 1912, which it had been unanimously decided to accept. The fifth Congress was then declared to have terminated.

## VISITS AND EXCURSIONS.

The Reception Committee in Copenhagen had arranged for the afternoons of the days during which the Congress lasted an attractive programme of visits to works and of entertainment for the members and ladies accompanying them. The events included a visit to the Carlsberg Breweries and the new Carlsberg Glyptotheca; a reception of the members of the Congress by the Danish Association of Civil Engineers at the Royal Shooting Club, Copenhagen; visits to the Free Port of Copenhagen; the Royal Danish Porcelain Works; the Frederiksberg Refuse Destruction and Electric Lighting Power Plant; the new Central Railway Station; a reception by the Mayor and City Council at the Town Hall, followed by an entertainment in the Tivoli Gardens; visits to Burmeister & Wain's Engineering and Shipbuilding Yards, and to the Polytechnic Academy and the State Testing Laboratory. A motor drive, which included a visit to the Trifolium Dairy, was also organised for the ladies. On Thursday evening, the 9th, the members witnessed a performance at the Royal Theatre. On Friday, the 10th, an extended excursion was made to Skodsborg, where the members were entertained to dinner, and on Saturday, the 11th, an excursion was made to Elsinore, about thirty miles distant from Copenhagen, to see the shipbuilding yards and Kronborg Castle. At Marienlyst, Elsinore, the members and the ladies accompanying them were entertained at a farewell dinner.

An extended tour, which lasted five days, was arranged after the closing of the Congress, in which a number of members who were able to spare the time remained to take part. On the evening of the 12th a large party proceeded by steamer to Aalborg, to visit the cement works at that place. From there they were conveyed by rail to Skagen, to inspect the great works which have been constructed there for the preservation of the North Sea coast.

## O B I T U A R Y.

HILARY BAUERMAN died at his residence in Balham on Sunday morning, December 5, at the age of seventy-six. He had been ailing for some time previous to his death, and had, indeed, been seriously ill for nearly three months prior to that event, the immediate cause of which was heart failure. Mr. Bauerman—or, to accord him the title to which he was entitled by reason of his professorship at the Ordnance College, Woolwich, Professor Bauerman—was one of the most distinguished and valuable members of the Iron and Steel Institute, at whose meetings he was a constant attendant, and to whose Proceedings he made many valuable contributions. For his services to metallurgical science he was, in 1904, elected an Honorary Member of the Institute, and was, with one exception, the only British member so distinguished, the exception being H.R.H. the Prince of Wales, who accepted honorary membership of the Institute a year later. He received his technical education at the Royal School of Mines, of which he was one of the first Associates. This school—known originally as the Government School of Mines and of Science applied to the Arts—was opened in 1851 at the Museum in Jermyn Street, and Professor Bauerman was a student from the date of the opening until 1853. In the latter year he went to Germany, where he entered the Bergakademie of Freiberg in Saxony, and on completing his mining and metallurgical course he came back to England, and was shortly afterwards appointed on the staff of the Geological Survey of Great Britain as assistant geologist. In 1858 he was appointed geologist to the North American Boundary Commission, and for the next five years was employed in the work of the Commission in Canada and the United States. The next twenty-five years of his life were spent in surveying and exploring the mineral resources of many parts of the world, and in this capacity he visited Arabia and Asia Minor, India, Brazil, North and South Carolina, Colorado and Granada, Mexico and Peru, Michigan and Missouri, and—in Europe—Lapland, Portugal, Savoy, and Sweden. Indeed, during this period, and at subsequent times, he visited practically every country in Europe, and on various occasions reported on mineral lands in widely scattered areas. Amongst the official capacities in which he served may be mentioned those in which, on the recommendation of the late Dr. Percy, he reported on the Mineral Resources of Cyprus, and on the Production of Iron in India, respectively.

The experience thus acquired qualified him in an exceptional degree for the positions he subsequently filled—as joint examiner in mining and metallurgy for the Science and Art Department from the year 1874 to 1879; as examiner in mining, Science and Art Department, from 1880 to 1898; as lecturer on metallurgy at Firth College, Sheffield, in 1909.—ii.

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1883; and his final appointment in the year 1888 as Professor of Metallurgy at the Ordnance College, Woolwich, which post he held until 1906. As a teacher he was singularly successful, his wide experience, retentive memory, and logical habit of mind peculiarly qualifying him to lecture on those subjects which he had so thoroughly made his own. He was an accepted authority, not in this country alone, but also abroad, where his attainments were held in the highest esteem, alike in geology, metallurgy and chemistry, and in crystallography and mineralogy; and he was the author of numerous important text-books, amongst which may be enumerated a standard treatise on "The Metallurgy of Iron," and two works, entitled respectively "Descriptive Mineralogy" and "Systematic Mineralogy." He was also joint author with J. A. Phillips of the important work on "Elements of Metallurgy," which was for many years accepted as the standard work on the art of extracting metals from their ores. He was a constant contributor to technical magazines and newspapers, and wrote numerous papers, which were read before the various societies of which he was a member; in addition to which he was an accomplished linguist, and spoke English, French, and German with equal facility. These societies included the Institution of Civil Engineers, of which he became an Associate Member in 1873, and by which he was, in 1897, awarded the Howard Prize; and the Geological Society, of which he became a Fellow in 1863, and served on the Council for the years 1874-1880, 1881-1888, 1894-1898. He was also an Honorary Member of the Chemical Society, of the Metallurgical and Mining Society of South Africa, and of the Institution of Mining and Metallurgy, which in 1906 awarded him a gold medal. As a juror in mining and metallurgical exhibitions his services were naturally in universal request, and he served on the juries of the Paris Exhibition of 1878, the Inventions Exhibition in London in 1884, the Antwerp Exhibition of the same year, the Chicago Exhibition of 1893, the Paris Exhibition of 1900, the St. Louis Exhibition of 1904, and the Franco-British Exhibition of 1908. In connection with the Collective Pig Iron Exhibit, shown in the British Section of the latter exhibition, he prepared a series of models illustrating the composition of typical brands of pig iron, and the proportions, by volume, of the constituents, sulphur, silicon, phosphorus, manganese, carbon, and iron, per ton, for each grade.

Professor Bauerman was a warm supporter of the Iron and Steel Institute, on the Publication Committee of which he was appointed in 1905. He attended practically all the meetings of the last fifteen years, and took an active part in the discussion of papers, drawing upon his extensive experience for the elucidation of many abstruse points, and never failing to throw fresh light upon the subject under consideration. Amongst the papers which he contributed from time to time to the proceedings of the Institute are the following: "Iron and Steel at the Chicago Exhibition,"\* "The Gellivare Iron Ore Mines,"† "Iron Ore

\* *Journal of the Iron and Steel Institute*, 1893, No. II.

† *Ibid.*, 1899, No. I.

Deposits of the Ural," \* "Iron and Steel at the Universal Exhibition, Paris," † "Mining and Metallurgy at the St. Louis Exhibition," ‡ "The Erzberg of Eisenerz," § and "Iron and Steel at the Franco-British Exhibition." ||

The funeral of Professor Bauerman took place on Friday, December 10, at Brookwood Cemetery, where, in accordance with his wishes, his remains were cremated. Most of the learned and scientific institutions and societies with which he was connected were represented at the funeral, which was also attended by a large number of those personal friends to whom his genial and kindly nature had greatly endeared him.

JOHN CLOWES BAYLEY died on October 10, 1909, at the age of seventy-five. He began his business career at the steel armour-plate works of Messrs. John Brown & Co., Ltd., Atlas Works, Sheffield, with the growth of which firm he was intimately associated, and ultimately became the London manager of the company, a position he held for twelve years. In this capacity he secured for the firm the first contract with the British Government for armour-plates for H.M.S. *Resistance*, and for many years afterwards negotiated with the Admiralty other contracts of greater importance. On account of his knowledge of languages he was selected as the representative of the Atlas Works to visit Russia, Turkey, Belgium, Spain, and other countries, where he was successful in securing many important contracts. In 1878 he visited Paris to represent his firm's interests at the International Exposition of that year. He was one of the founders of the firm of Brown, Bayley & Dixon, which was established in Sheffield in 1871, their interest being ultimately transferred to Brown Bayley's Steelworks, Ltd. He was also one of the original directors of Frederick Braby & Co., Ltd., of London. When the tramway systems of the world began to develop upon an extensive scale, he took an active part in many enterprises, and co-operated in financing, constructing, and working lines in many parts of the world. He was an early concessionaire of hæmatite iron-ore deposits of Bilbao, Spain, and took a prominent part in the formation of the Bilbao Iron Ore and Railway Company, which, since 1871, has supplied many millions of tons of the raw material for Bessemer steel manufacture in this country. He was elected a member of the Iron and Steel Institute in 1873.

THOMAS CARLISLE died recently at Nelson, British Columbia, at the age of fifty-two. He was formerly manager of the Bessemer department of the Moss Bay Hæmatite Iron and Steel Works, at Workington. He was elected a member of the Iron and Steel Institute in 1903.

ARCHIBALD HENDRY DUNNACHIE died in February 1909. He was a son of Mr. James Dunnachie, and was general manager of the Glenboig Union Fireclay Company, Ltd., at Glenboig. He had had a wide

\* *Journal of the Iron and Steel Institute*, 1898, No. I.

‡ *Ibid.*, 1904, No. II.

§ *Ibid.*, 1907, No. III.

† *Ibid.*, 1900, No. II.

|| *Ibid.*, 1908, No. III.



experience in some of the largest steelworks in France, and was much interested in the chemical aspects of the refractory materials industry, and ably supervised the well-equipped laboratory installed at Glenboig. He was elected a member of the Iron and Steel Institute in 1890.

HENRY HEYWOOD died at his residence, Whitla Court, Cardiff, on July 11, 1909. Born in 1842, he was the eldest son of the late Mr. James Heywood, of Worksop, and went to Cardiff in 1870. In 1872 he was joined in business by his brother, Mr. Charles Heywood, under the title of Heywood Bros., iron ore importers and agents. In early life he had spent some years in the engineering department of Messrs. John Brown, at Sheffield, and throughout his career he maintained a deep and active interest in engineering questions. He was chairman of Bell's Asbestos Company, and a director of other industrial concerns, and was elected a member of the Iron and Steel Institute in 1879.

HENRY MONTAGUE HINGLEY died suddenly on October 1, 1909, in his fifty-sixth year. He was a brother of Sir George Hingley, and a nephew of the late Sir Benjamin Hingley. After the death of Sir Benjamin he and his brother carried on the well-known ironworks belonging to the firm of N. Hingley & Sons, Ltd., at Netherton and Old Hill. Elected a member of the South Staffordshire Mine Drainage Commission to fill the vacancy caused by the death of his uncle, he subsequently became chairman of the Old Hill Committee. He was elected a member of the Iron and Steel Institute in 1907.

RICHARD LAYBOURNE died on October 25, 1909, at his residence, The Firs, Malpas, Newport, Mon., in his eighty-fifth year. He was apprenticed at the Hareshaw Ironworks, in Northumberland, afterwards being engaged with E. B. Wilson & Co., at the Railway Foundry, Leeds, later serving with the London and North-Western Railway at Wolverton, and then becoming rolling-stock superintendent of the Monmouthshire Railway. After remaining with the last named for fourteen years, he was appointed general manager of the Rhymney Iron Company, and designed and erected Bessemer steelworks and plant capable of producing 1000 tons a week. In 1878 he assumed an active part in the management of the Isca Foundry and Engineering Company at Newport. He was a member of the Institution of Civil Engineers, and an original member of the Iron and Steel Institute.

CHARLES HANSON MACKAY died on September 9, 1909. He received his education at the Glasgow High School and the West of Scotland Technical College. For two years he gained experience as an electrical engineer's apprentice, and in 1899 he started as a marine engineer apprentice with Messrs. William Beardmore & Co., Ltd. At the close of his apprenticeship, in 1904, he was engaged in the erection of electric overhead cranes, in both shipyard and engine shop. In 1906 he received an appointment at Port Talbot Steelworks as electrician, a post he held for one year. He then proceeded to Bilbao, on behalf of

Messrs. Lamberton & Co., Ltd., to erect a plate-mill at the steelworks of Martinas Rivas. The period allowed to him to erect it and run it was one year, and so well did he accomplish this task that on the expiration of that term he was appointed by Martinas Rivas as his steelworks manager. He was shortly after appointed director of the steelworks, a position which he held until his death. He was elected a member of the Iron and Steel Institute in 1909.

LUDWIG MOND died at his residence, near Regent's Park, on the morning of Saturday, December 11, at the age of seventy, having been born on March 7, 1839, at Cassel, in Germany. He was educated at the Polytechnic School of his native town, and, subsequently, studied chemistry at Marburg and at Heidelberg. At the latter university he was under the tuition of the celebrated Bunsen. He early evinced considerable inventive talent, one of the first processes which he devised having been a method for the recovery of the sulphur lost in the black ash waste of the Leblanc soda process. At the age of twenty-three he came to England, where he was appointed chemist at the works of Messrs. Hutchinson & Earle, of Widnes, but two years later he returned to the Continent, where he was engaged in the installation of a soda process factory on the Leblanc system at Utrecht. In 1867 he came back to England, and henceforward identified himself with this country, which became his permanent home.

The turning point in Dr. Mond's career was the friendship formed as far back as 1862 with Sir John Brunner, at that time Mr. J. T. Brunner, with whom, ten years later, he entered into partnership for the purpose of carrying on the manufacture of chemicals. An estate having been purchased in the vicinity of the Cheshire salt deposits, the partners commenced the manufacture of alkali by the Solvay process, which had attracted the attention of Dr. Mond during a visit to the Continent in 1872, and the earlier difficulties having been skilfully overcome, and success attained in minor details, the problem of the recovery of the ammonia employed as a reagent in the ammonia soda process was attacked and solved. Another of the discoveries due to Dr. Mond at about this time was that of means for the recovery of the chlorine lost in the form of calcium chloride, and this process, taken in conjunction with the other, firmly established the success of the Solvay method as a competitor with the Leblanc process for the production of chloride of lime.

The most important work achieved by Dr. Mond was, however, the invention of Mond gas, and its application for industrial purposes. His investigations on the employment of cheap bituminous fuel, which culminated in this discovery, were the outcome of many years' work. The ultimate success of Mond gas for power purposes led to the installation of large works in South Staffordshire for the conversion of the cheap fuel obtainable in the district.

To his attainments as a mechanical engineer, Dr. Mond added those of a metallurgist of distinction, his chief work in this direction being the discovery of a process for the extraction of nickel from its ore. In

conjunction with Carl Lange and Friedrich Quincke, he elucidated the chemistry of carbonyl compounds by the isolation of nickel carbonyl, and subsequently of other metals. By means of this compound it was found possible to devise a process for the production of metallic nickel at comparatively low temperatures, with the result that the economic difficulties frequently experienced in the manufacture of nickel on a commercial scale were greatly reduced. The result of preliminary experiments carried out at Smethwick led to the development of the process now carried out so successfully by the Mond Nickel Company at Swansea.

Dr. Mond's many attainments naturally secured for their possessor numerous distinctions. The King of Italy conferred upon him the Grand Cordon of the Crown of Italy, and he had received honorary degrees in the Universities of Padua, Heidelberg, Victoria, and Oxford. He was made a Fellow of the Royal Society in 1891, and was also a Fellow of the Institute of Chemistry and of the Chemical Society. To these institutions he presented numerous scientific contributions, while his benefactions to the Royal Society enabled it to publish the International Catalogue of Scientific Papers. His generosity in the cause of scientific advancement prompted him to endow a laboratory for research in pure unapplied science, which was formally opened in 1869 as the David Faraday Laboratory, under the control and management of the Royal Institution. In 1889 he was elected President of the Society of Chemical Industry, and at the Meeting of the British Association at Liverpool of 1896 he was elected President of the Chemical Section. He had also been appointed President of the Chemical Society for the present year, but the state of his health precluded his serving in that capacity. He was elected a member of the Iron and Steel Institute in 1895.

HUGO SACK died suddenly on June 23, 1909, at Offidilln, near Düsseldorf. He was born at Loeben, near Lützen, Saxony, in 1860, where his father, Rudolf Sack, owned an estate. In 1863 his family moved to Leipzig, where his father founded an engineering works for the manufacture of agricultural machinery, in which his son Hugo, after completing his school education, gained his first practical experience as an engineer. He then went through a course of technical study at Mittweida and at the Karlsruhe Technical High School. In 1882 he returned to his father's works, leaving them again soon after, however, to take up work in Westphalia and the Rhine province. He was subsequently commissioned by a British firm to erect a wire-drawing plant in Spain, near Bilbao, of which he continued for a year to act as manager. On returning to Germany, he founded, in 1891, the engineering works of Sack and Kiesselbach at Rath, near Düsseldorf, which, under the skilful management of himself and his partner, soon developed into the important undertaking now so well known under that name. In 1899 he resigned the management of these works and founded at Rath the firm of Sack, Limited, to the development of which, to the end of his life, the whole of his activities were devoted. Here he found great scope for his remarkable talent as an engineer, and ample opportunity to realise his inventive genius in the construction of machinery of all kinds, and more especially

rolling-mills. Among other inventions he was successful in perfecting the construction of the Sach mill, a universal rolling-mill on lines proposed by him as far back as the 'eighties, for parallel girders with wide flanges. A description of his universal mill and of its operation is contained in a paper read by him before the Iron and Steel Institute in 1889. He was elected a member of the Iron and Steel Institute in 1894.

CARL SETTERWALL died in August 1909, at the age of sixty-seven. He was the founder of the iron and steel exporting business of Carl Setterwall & Co., Stockholm, Sweden, and was elected a member of the Iron and Steel Institute in 1898.

JOHN SHAW, chairman of John Shaw, Ltd., of the Yorkshire Wire Rope Work, Sheffield, died at sea on the s.s. *Pericles* on July 27, 1909, at the age of sixty-eight. He possessed much knowledge of the wire-working trade, having spent many years in the works which had been established by his father in 1820. In 1868 he succeeded to the sole control of the business, to which had been added that of wire-rope manufacturers. The latter portion of the business proved so successful that in 1869 the firm had to remove to new works which have subsequently had to be enlarged several times. He was elected a member of the Iron and Steel Institute in 1905.

HENRY FRANCIS TAYLOR died on August 16, 1909, after a brief illness. He was head of the firm of Taylor & Sons, Ltd., engineers, of the Briton Ferry Foundry, and a director of the Villiers Tinsplate Company, Ltd. He was elected a member of the Iron and Steel Institute in 1904.

EBENEZER ROWLAND THOMAS died on October 21, 1909, at his residence, Heulwen, Porthcawl, in his sixty-eighth year. His career began with an official position on the railways in the Llanelly district. Subsequently he removed to Newport, Mon., where he took up the agency of the Blaenavon Company, Ltd., besides carrying on business as an iron merchant. Having purchased the Pantmawr Limestone Quarries, he recently removed to Porthcawl. He was elected a member of the Iron and Steel Institute in 1896.

JOHN TIMMINS died suddenly on October 6, 1909. He was for twelve years chief engineer of the Barrow Hæmatite Iron and Steel Company, of Barrow. He was well known in the district, and was concerned with many important developments at the works named, particularly in respect of the new gas plant. He was elected a member of the Iron and Steel Institute in 1903.

THOMAS TURNER, managing director of Messrs. Andrew Barclay, Sons, and Co., Ltd., Caledonia Works, Kilmarnock, died on Saturday, August 7, 1909, at the age of fifty-three. He was a native of Blaydon-on-Tyne, and in his youth distinguished himself as a Whitworth scholar. Electing

to be an engineer, he served his apprenticeship on Tyneside with Messrs. Nicholson & Wilson, and subsequently had a wide and varied practical experience, working his way up from post to post, and always improving his position. During his career he was successively steelworks manager to Messrs. Joseph Fenton & Sons, Sheffield; editor of the *Mechanical World*, published in Manchester; works manager to the New British Iron Company, Corngreaves; and works manager to the Shelton Iron and Steel and Coal Company, Ltd., Stoke-on-Trent. He had also a large experience of practical engineering in India. Under his able and energetic management the works at Kilmarnock were very largely reconstructed and enlarged and the business of the firm greatly extended. Always keeping the company's interests foremost in his mind, Mr. Turner devoted unceasing attention to the business, and the present extensive and admirably equipped works are a standing monument to his foresight and capacity. He was a member of the Institute of Mechanical Engineers; a member of the Council of the Federated Mining Institute of Great Britain and of the West of Scotland Iron and Steel Institute; a member of the Institute of Mining Engineers and of the Institution of Engineers and Shipbuilders in Scotland; and for some time past he filled the office of President of the Kilmarnock Branch of the Engineering Employers' Federation. He was elected a member of the Iron and Steel Institute in 1886.

# ADDITIONS TO THE LIBRARY

DURING THE SECOND HALF OF 1909.

Title.	By whom Presented.
"Annuario della Industria Mineraria, Metallurgica, e Chimica Italiana," anno II. 1909. 8vo, pp. 580. Turin. 1909.	<i>Rassegna Mineraria.</i>
"Mines and Quarries: General Report and Statistics for 1908. Part I. District Statistics." Fcap. folio, pp. 48. London. 1909.	The Under-Secretary of State.
"The Nurnberg Gas Engine." By R. Bechtel. (A paper read before the Birmingham Association of Mechanical Engineers, February 6, 1909.) 8vo, pp. 46.	The Author.
"Coal Shipment and the laying out of Staithe Heads, with special reference to Anti-Breakage Appliances." By J. Kirsopp, jun. (A paper read before the Institution of Mining Engineers, September 17, 1902.) 8vo, pp. 188.	The Author.
Canada, Department of Mines: "Investigation of the Peat Bogs and Peat Industry of Canada during the Season 1908-9." By E. Nystrom and S. A. Anrep. Bulletin No. 1. 8vo, pp. 25. Ottawa. 1909.	The Director of Mines.
Canada, Department of Mines: "Peat and Lignite: their Processes and Uses in Europe." By E. Nystrom. 8vo, pp. 247. Ottawa. 1908.	The Director of Mines.
Canada, Department of Mines: "Report on the Iron Ore Deposits of Nova Scotia." By J. E. Woodman. Part I. 8vo, pp. 226. Ottawa. 1909.	The Director of Mines.
"On the Effect of Internal Friction in Cases of Compound Stress." By G. H. Gulliver. (Reprint from the <i>Proceedings of the Royal Society of Edinburgh</i> . Vol. XXIX., Part V.) 8vo, pp. 6.	The Author.
"On the Friction at the Extremities of a Short Bar subjected to a Crushing Load, and its Influence upon the Apparent Compression Strength of the Material." By G. H. Gulliver. (Reprint from the <i>Proceedings of the Royal Society of Edinburgh</i> . Vol. XXIX., Part V.) 8vo, pp. 13.	The Author.
"Welche Temperaturen Können wir mit unserengewöhnlichen." By J. von Ehrenwerth (Sonderdruck aus <i>Metallurgie</i> . Vol. VI., No. 10.) 4to, pp. 13.	The Author.
"The Volcanic Origin of Coal and Modern Geological Theories." By A. T. Fraser. 8vo, pp. 21. 1909.	Robert Banks & Son.
"Contribution à l'Étude des Fours Électriques appliquées à la Fabrication des Fers et Aciers." By A. Keller (Mémoire présenté au VII <sup>e</sup> Congrès de Chimie à Londres). 8vo, pp. 66. 1909.	The Author.
Engineering Standards Committee: "British Standard Specification and Sections of Bull-head Railway Rails." (Second issue, revised July 1909.) Fcap. folio, pp. 10. With 12 plates. London. 1909.	The Committee.
Engineering Standards Committee: "British Standard Specification and Sections of Flat-bottom Railway Rails." (Second issue, revised July 1909.) Fcap. folio, pp. 10. With 20 plates. London. 1909.	The Committee.

Title.	By whom Presented.
Engineering Standards Committee: "British Standard Specification for Cast Iron Pipes for Hydraulic Power." Fcap. folio, pp. 8. With 8 plates. London. 1909.	The Committee.
"Monografía de la Sociedad Altos Hornos de Vizcaya de Bilbao," año 1909. pp. 63. Illustrated. Barcelona. 1909.	The President and Council of the Sociedad Altos Hornos de Vizcaya.
"The Influence of the Railroad of the United States and Canada on the Mineral Industry." By James Douglas. (Paper read before the Institution of Mining and Metallurgy, October 29, 1909.) 8vo, pp. 52.	The Author.
"Die Industrieausstellung in Nancy, 1909." By A. Gouvy. (Sonder-Abdruck aus der Zeitschrift <i>Stahl und Eisen</i> , 1909, No. 33.) 8vo, pp. 6.	The Author.
"La Trempe et le Recuit de l'Acier." By L. Grenet. (Extrait du <i>Bulletin et Comptes Rendus Mensuels de la Société de l'Industrie Minière</i> , April 1909.) 8vo, pp. 26.	The Author.
"Les Transformations du Fer et de l'Acier." By L. Grenet. (Extrait du <i>Bulletin de la Société Chimique de France</i> , 4th Series, Vol. V., 1909.) 8vo, p. 7.	The Author.
"The Geology of Ore Deposits." By H. H. Thomas and D. A. MacAlister. 8vo, pp. 416. Illustrated. London. 1909.	Edward Arnold.
Canada, Department of Mines: "Report on the Tungsten Ores of Canada." By T. L. Walker. 8vo, pp. 56. Ottawa. 1909.	The Director of Mines.
"Die Selbstkostenberechnung für Hüttenwerke insbesondere für Eisen- und Stahlwerke." By A. Schuchart. 8vo, pp. 76. Dusseldorf. 1909.	Verein deutscher Eisenhüttenleute.
Canada, Department of Mines: "Report on the Chrome Iron Ore Deposits in the Eastern Townships, Province of Quebec." By F. Cirkel. 8vo, pp. 141. Ottawa. 1909.	The Director of Mines.
Canada, Department of Mines: "Report on the Investigation of an Electric Shaft Furnace, Domnarfvät, Sweden." By E. Haanel. 8vo, pp. 38. Ottawa. 1909.	The Director of Mines.
"Laboratory Notes on Iron and Steel Analyses." By Walter Macfarlane. 8vo, pp. 462. London. 1909.	The Author.
Victoria, Department of Mines: "Annual Report of the Secretary for Mines for the Year 1908." Fcap. folio, pp. 182. Melbourne. 1909.	The Secretary for Mines.
Transvaal Mines Department: Geological Survey, Memoir No. 4, "The Geology of the Waterberg Tin Fields." By H. Kynaston and E. T. Mellor, with a chapter on their Economic Aspects, by U. P. Swinburne. 8vo, pp. 124. Pretoria. 1909.	The Director of Mines.
Victoria, Department of Mines: Geological Survey, Memoir No. 7, "The Deep Leads of Victoria." By S. Hunter. Fcap. folio, pp. 142; Memoir No. 8, "Report on the Lower Powlett, Cape Paterson, and Inverloch Quarter Sheets." By W. H. Ferguson. Fcap. folio, pp. 14. Victoria. 1909.	The Secretary for Mines.
Western Australia, Department of Mines: "Report on the Progress of Mining in the Districts between Lenra and Wiluna." By A. Montgomery. 8vo, pp. 88; "Report on the Waverley or Siberia District." By A. Montgomery. 8vo, pp. 26. Perth. 1909.	The Agent-General for Western Australia.
Western Australia, Geological Survey: Bulletin No. 35, "Geological Report upon the Gold and Copper Deposits of the Phillips River Goldfield," by H. P. Wodward; and a "Description of the Crystalline Rocks of the District," by E. S. Simpson and L. Glauert. 8vo, pp. 109. Perth. 1909.	The Agent-General for Western Australia.

Title.	By whom Presented.
"Mines and Quarries: General Report and Statistics for 1908; Part II., Labour." Fcap. folio, pp. 129. London. 1909.	The Under-Secretary of State.
Engineering Standards Committee: "Report on the Standard Dimensions for the Threads of Sparking Plugs (for internal combustion engines)." Fcap. folio, pp. 7. London. 1909.	The Committee.
Engineering Standards Committee: "British Standard Specification for Keys and Keyways." Fcap. folio, pp. 11. London. 1909.	The Committee.
Engineering Standards Committee: "British Standard Specification and Sections of Steel Fishplates for British Standard Bull-head Railway Rails (for rails from 70 lbs. to 100 lbs. per yard inclusive), and for British Standard Flat-bottom Railway Rails (for rails from 20 lbs. to 100 lbs. per yard inclusive)." Fcap. folio, pp. 11, with 5 tables. London. 1909.	The Committee.
Engineering Standards Committee: "British Standard Specification for Wrought Iron of Smithing Quality for Shipbuilding, Grade D." Fcap. folio, pp. 10. London. 1909.	The Committee.
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"Der Graphit, eine technische Monographie." By A. Haenig. 8vo, pp. 224, with 29 illustrations. Vienna. 1909.	A. Hartleben.
"Theoretische und Kinematographische Untersuchung von Dampfhämmern mit Selbsttätiger Schiebersteuerung." By O. Fuchs. 8vo, pp. 20, with 13 illustrations in the text and 2 tables. Berlin. 1909.	J. Springer.
Royal Commission on Mines: "Report of a Committee appointed by the Royal Commission on Mines to inquire into the Causes of and Means of Preventing Accidents from Falls of Ground, Underground Haulage, and in Shafts." Fcap. folio, pp. 182. London. 1909.	The Chief Inspector of Mines.
"Mines and Quarries: General Report and Statistics for 1908; Part III., Output." Fcap. folio, pp. 272. London. 1909.	The Under-Secretary of State.
Western Australia: "Report of the Department of Mines for the Year 1908." Fcap. folio, pp. 250. Perth. 1909.	The Agent-General for Western Australia.
"Die Spezialstähle in Theorie und Praxis." By W. Giesen. 8vo, pp. 80. Freiberg. 1909.	The Author.
"The History of the Dico Iron Ore Company Ltd." Folio, pp. 25. London. 1909.	The Dico Iron Ore Co. Ltd.
Geological Survey of Canada: "Reports on a Portion of Algoma and Thunder Bay Districts, Ontario," by W. J. Wilson, and "On the Region lying North of Lake Superior between the Pic and Nipigon Rivers, Ontario," by W. H. Collins; 8vo, pp. 24; "The Coalfields of Manitoba, Saskatchewan, Alberta, and Western British Columbia," by D. B. Dowling. 8vo, pp. 111; "The Whitehorse Copper Belt, Yukon Territory," by R. G. McConnell. 8vo, pp. 63; "Catalogue of Publications of the Geological Survey of Canada" (revised to January 1, 1909); 8vo, pp. 181. Ottawa. 1909.	The Director, Department of Mines.
"Analyse Thermique et Métallographie Microscopique." By E. Rencade. With a preface by H. Le Chatelier. 8vo, pp. 176. Paris. 1909.	Librairie Hachette et Cie.
"The Prevention of Industrial Accidents": No. 1, General. 8vo, pp. 194. New York. 1909.	The Fidelity and Casualty Co.



Title.	By whom Presented.
Missouri Bureau of Geology and Mines: Vol. VII., 2nd Series, "The Geology of Morgan County," by C. F. Marbut. 8vo, pp. 97; Vol. VIII., 2nd Series, "The Geology of Pike County," by R. R. Rowley. 8vo, pp. 122; Vol. IX., Parts I. and II., "Geology of the Disseminated Lead Deposits of St. François and Washington Counties," by E. R. Buckley, 8vo, pp. 250, with 120 plates. Jefferson City, Missouri.	The Director, Missouri Bureau of Geology and Mines.

The following books have been purchased :—

- "Traitements Thermiques des Produits Métallurgiques, Trempe, Recuit, Revenu." By L. Guillet. 8vo, pp. 631. Paris.
- "Leçons sur les Alliages Métalliques." By J. Cavalier. 8vo, pp. 466. With 24 plates. Paris.
- "Report on the Circumstances attending an Explosion which occurred in the Workings of the West Stanley Colliery on February 16, 1909." By R. A. S. Redmayne and R. D. Bain. Fcap. folio, pp. 23. London. 1909. [Cd 4788.]
- "The Mineral Industry: its Statistics, Technology, and Trade during 1908." Vol. XVII. 8vo, pp. 1073. New York. 1909.
- "Royal Commission on Mines: Second Report." Fcap. folio, pp. 297. London. 1909. [Cd 4820.]
- "Census of Production, 1907: Preliminary Tables Summarising the Results of the Returns received under the Census of Production Act, 1906." Fcap. folio, pp. 37. London. 1909. [Cd 4896.]
- "Die Härte der Festen Körper und ihre Physikalisch Chemische Bedeutung." Von V. Pöschl. 8vo, pp. 84. With four figures in the text and one table. Dresden. 1909.
- "Illustrierte Technische Wörterbücher in sechs Sprachen." Vol. V., "Eisenbahnbau und Eisenbahnbetrieb." 8vo, pp. 870. Berlin. 1909.

# INSTITUTIONS.

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Board of Trade.  
Chemical Society.  
City and Guilds Institute.  
Faraday Society.  
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## PROVINCIAL.

Birmingham University.  
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Manchester Association of Engineers.  
Manchester Geological and Mining Society.  
Mining Institute of Scotland.  
North-East Coast Institution of Engineers and Shipbuilders.

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## COLONIAL AND FOREIGN.

### Colonial.

Australasian Institute of Mining Engineers.  
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Canadian Mining Institute.  
Canadian Society of Civil Engineers.  
Department of Mines, Brisbane.  
Department of Mines, Melbourne.  
Department of Mines, Perth.  
Department of Mines, Sydney.  
Geological Survey of Canada.  
Geological Survey of India.  
Geological Survey of New South Wales.  
Mining Society of Nova Scotia.  
Mysore Geological Department.  
Royal Society of New South Wales.

### United States.

American Association for the Advancement of Science.  
American Foundrymen's Association.  
American Institute of Mining Engineers.  
American Iron and Steel Association.  
American Society of Civil Engineers.  
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Department of Commerce and Labour, Washington.  
Engineers' Society of Western Pennsylvania.  
Franklin Institute.  
Massachusetts Institute of Technology.  
New York Academy of Sciences.  
Ordnance Office, War Department, Washington.  
School of Mines, Columbia University, New York.  
Smithsonian Institution.  
United States Geological Survey.

COLONIAL AND FOREIGN—*continued.***Austria.**

K. K. geologische Reichsanstalt.  
Oesterr. Ingenieur- und Architekten-  
Verein.

**Belgium.**

Association des Ingénieurs sortis de l'École  
des Mines de Liège.  
Ministère de l'Intérieur.

**France.**

Comité des Forges.  
Société d'Encouragement pour l'Industrie  
Nationale.  
Société de l'Industrie Minérale.  
Société des Anciens Elèves des Écoles  
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Deutsches Museum.  
Königliche Bergakademie in Freiberg.  
Königliches Materialprüfungsamt.  
Verein deutscher Eisenhüttenleute.  
(Journal "Stahl und Eisen.")  
Verein deutscher Ingenieure.

**Italy.**

Reale Accademia dei Lincei.

**Peru.**

"Cuerpo de Ingenieros de Minas."

**Sweden.**

Geological Institution of the University of  
Upsala.  
Jernkontoret.

**JOURNALS.**

The following periodicals have been presented by their respective Editors :—

**UNITED KINGDOM.**

- |   |  |
|---|--|
| <p>"Biggs and Sons' Contractors' Record."<br/>"Cassier's Magazine."<br/>"Coal and Iron."<br/>"Colliery Guardian."<br/>"Concrete and Constructional Engineer-<br/>ing."<br/>"Contract Journal."<br/>"Electrical Engineer."<br/>"Electrical Engineering."<br/>"Electrical Review."<br/>"Electrical Times."<br/>"Electrician."<br/>"Engineer."<br/>"Engineer and Iron Trades Advertiser."<br/>"Engineering."<br/>"Engineering Review."<br/>"Hardware Trade Journal."<br/>"Illuminating Engineer."<br/>"International Marine Engineering."<br/>"Iron and Coal Trades Review."<br/>"Iron and Steel Trades Journal."<br/>"Iron Trade Circular."<br/>"Ironmonger."</p> | <p>"Ironmongers' Chronicle."<br/>"Machinery Market."<br/>"Marine Engineer."<br/>"Mechanical Engineer."<br/>"Page's Weekly."<br/>"Petroleum Review."<br/>"Phillips' Monthly Register."<br/>"Plumber and Decorator."<br/>"Practical Engineer."<br/>"Quarry."<br/>"Railway News."<br/>"Railway Times."<br/>"Royal Automobile Club Journal."<br/>"Science and Art of Mining."<br/>"Scientific Monthly."<br/>"Shipping World."<br/>"South African Engineering."<br/>"Statist."<br/>"Steamship."<br/>"Syren and Shipping."<br/>"Technical Index."<br/>"Tramway and Railway World."<br/>"Vulcan."</p> |
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## COLONIAL AND FOREIGN.

## Colonial.

- "Canadian Machinery."
- "Indian and Eastern Engineer."
- "Indian Engineering."
- "Indian Textile Journal."
- "New Zealand Mines Record."

## United States.

- "American Journal of Science."
- "American Machinist."
- "Bradstreets."
- "Electrochemical and Metallurgical Industry."
- "Engineering and Mining Journal."
- "Engineering Magazine."
- "Engineering News."
- "Industrial World."
- "Iron Age."
- "Iron Trade Review."
- "Machinery."
- "Mines and Minerals."
- "Mining World."
- "Power."

## Austria.

- "Oesterr. Zeitschrift für Berg- und Hüttenwesen."

## Belgium.

- "Bulletin de l'Union des Charbonnages de Liège."
- "Moniteur des Intérêts Matériels."
- "Revue Universelle des Mines."

## France.

- "Annales des Mines."
- "L'Écho des Mines."

- "Le Génie Civil."
- "Le Mois Scientifique et Industriel."
- "Portefeuille Economique."

## Germany.

- "Annalen für Gewerbe und Bauwesen."
- "Der Ingenieur."
- "Eisen-Zeitung."
- "Glückauf."
- "Jahresbericht des Vereins für die bergbaulichen Interessen in Obergamtsbezirk Dortmund."
- "Metallurgie."
- "Verein deutscher Eisen- und Stahl-Industrieller."
- "Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate."
- "Zeitschrift für praktische Geologie."
- "Zeitschrift für Werkzeugmaschinen und Werkzeuge."

## Italy.

- "Industria."
- "Rassegna Mineraria."

## Spain.

- "Ingenieria."
- "Revista Minera."

## Sweden.

- "Blad för Bergstandterings Vänner."
- "Svensk Export."
- "Teknisk Tidskrift."

The following periodicals have been purchased :—

## UNITED KINGDOM.

- "Chemical News."
- "Foundry Trade Journal."
- "Mining Journal."
- "Nature."

## COLONIAL AND FOREIGN.

## Colonial.

"Canadian Mining Journal."

## United States.

"Journal of the American Chemical Society."

## Austria.

"Bányászati és Kohászati Lapok."

"Berg und Hüttenmännisches Jahrbuch."

## Belgium.

"Annales des Mines de Belgique."

## France.

"La Technique Moderne."

"Revue de Métallurgie."

"Revue Générale des Sciences."

## Germany.

"Chemiker Zeitung."

"Geologisches Zentralblatt."

"Giesserei Zeitung."

"Montan Zeitung."

"Zeitschrift für angewandte Chemie."

## Roumania.

"Moniteur du Pétrole Roumain."

"Revue du Pétrole."

## SECTION II.

# *NOTES ON THE PROGRESS OF THE HOME AND FOREIGN IRON AND STEEL INDUSTRIES.*

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Assistant Secretary, and others.

# IRON ORES.

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### I.—OCCURRENCE AND COMPOSITION.

**Formation of Ore Deposits.**—A. C. Lane\* endeavours, from an investigation of the mine waters of the Michigan iron mines, to account for the precipitation of the iron ores of the Michigan range by concentration. Analyses of the waters from the Vulcan, Ishpeming, Ironwood, Hurley, Bessemer, Champion, and the Republic mines are given. The author found that it was not necessary to go far from the surface to obtain chlorine that was not associated with sodium, and might be called calcium chloride. This cannot be due to surface or accidental organic contamination. The calcium chloride occurs not only in iron, but in copper mines and the older Palæozoics, and it has been attributed to the early sea water; but the waters of the iron mines contain proportionately much more sulphates than the waters of the copper country. The chloride, and to some extent the sulphate, are regarded as the form in which transportation took place. If the agent of precipitation contained sodium carbonate, iron carbonate would have formed, but if it contained sodium silicate, silica and iron would have been precipitated. The early concentration of the iron ore probably took place in the Huronian seas, which were a solution mainly of chlorides in which neither calcium nor sodium exceeded four-tenths the amount of chlorine. Into such waters the chemical decay of rocks introduced sodium silicate and carbonate, which threw down the iron as oxide or carbonate with silica.

**Iron Ore in Wales.**—It is reported† that magnetic iron ore yielding up to 68·70 per cent. iron has been discovered in Cader,

\* Paper read before the Canadian Mining Institute, *Mining World*, vol. xxxi. pp. 413-416.

† *Colliery Guardian*, vol. xcvi. p. 415.

North Wales. Whether it is a workable deposit has yet to be proved, but so far the features are promising. In the past, however, the North Wales magnetic iron and hæmatites have not proved to be of great value.

**Iron Ore in Austria.**—According to G. Ölwein,\* Austria possesses a reserve of iron ore sufficient to supply the needs of her own iron industry for some considerable time, the ores in Styria being estimated at about 75 million tons, those in Bohemia at 250 million tons, and in Carinthia at 20 million tons. This ore would yield about 140 million tons of pig iron, so that, the annual output being at present about 1·1 million tons, the ore supply is sufficient for one hundred and twenty-seven years, without taking into account the iron ores in Bosnia and Herzegovina.

J. Lowag† describes the iron-ore deposit at Eisenstein in the Böhmerwald. The ore is highly manganiferous brown ironstone, averaging 45 to 50 per cent. of iron, and the deposit is 7 to 10 feet in thickness. It is estimated that about a million tons of paying ore are in sight above the old adit, driven about three hundred years ago.

**Iron Ore in France.**—G. Vandeville,‡ in an account of the mining and metallurgical industries of Meurthe-et-Moselle, describes the iron-ore deposits of the district. They form two distinct areas, that of Briey and that of Nancy. The latter, which is less important, is separated from the former by a sterile zone of about 40 kilometres in width. The mining concessions in the Nancy basin may be estimated to contain 200 millions of tons, whereas those in the Briey district have been estimated to contain 2300 millions of tons. A further 600 millions has been estimated to exist in the areas not yet taken up, so that altogether over 3000 tons of iron ore are available in the Meurthe-et-Moselle region. In 1908 the production was 8,486,000 tons, of which the Briey mines produced 4,368,000 tons. The ore formation in the Nancy district comprises three layers—the upper, lower, and middle—of a maximum thickness of 2·50 metres. In the Briey district the formation consists of the following layers, starting from the lowest: (1) the green, brown, and black siliceous layer; (2) the grey layer, the richest and most regular; and (3) the red layer, which is actively worked for calcareous ore at Longwy and Villerupt. Almost immediately above these deposits is found ferruginous limestone containing up to 30 per cent. of iron, which furnishes a valuable flux for the siliceous ores of Longwy. Some trouble is experienced with water, and special methods of working, which are described, have to be adopted.

\* *Montan Zeitung*, vol. xvi. pp. 186-187.

† *Ibid.*, p. 372.

‡ *Revue Universelle des Mines*, vol. xxvii. pp. 109-135.



T. Callot\* describes the oolitic iron-ore deposits of Lorraine. The basin of Briey has been divided by geologists into four subsidiary basins, the separation being based on the numerous faultings encountered, which are of considerable importance from the point of view of geology and hydrology. A sketch map is given showing the main faults, and also the outcrop of the ferruginous deposits and the contours of the grey seam. The faults are the boundaries of the basins, which are named Bassin de l'Orne, de Montiers-Avril, d'Aumetz-Tucquegnieux, and de Landres. The main feature of the ore is the constant presence of phosphorus. The ore is a hydrated oxide of iron,  $\text{Fe}_2\text{O}_3$ , with a clayey, calcareous, or siliceous gangue, and varies in colour from yellow brown to red brown. An average complete analysis would show—

	Per Cent.
Silica . . . . .	5.60
Alumina . . . . .	4.61
Iron peroxide . . . . .	39.77
Iron protoxide . . . . .	10.00 to 16.00 (iron = 31 to 40 per cent.)
Phosphoric anhydride . . . . .	1.85 (phosphorus = 0.8 per cent.)
Manganous oxide . . . . .	0.42 (manganese = 0.32 per cent.)
Lime . . . . .	12.00 to 18.00
Magnesia . . . . .	1.22
Sulphuric acid . . . . .	0.22 (sulphur = 0.08 per cent.)
Loss by ignition . . . . .	18.37

In the grey seam the proportion of phosphorus to iron is practically constant, the average analysis being: iron, 33.62 per cent.; phosphorus, 0.73 per cent.; or a phosphorus content of about 2.15 per cent. per unit of iron.

Ironstone having been traced near Lanfains, between Brest and St. Malo, research work is being carried out, the first results of which tend to show that there exist in that part of France important veins of first-class quality.†

**Iron Ore in Germany.**—E. Haarmann‡ describes the Hüggl iron-ore deposit near Osnabrück, from which the ore is won by open-cast and underground working, and smelted at the Georgsmarienhütte. The output in 1908 was 1448 tons of brown ironstone and ochre with 24.94 per cent. of iron, and 12,148 tons of spathic ore averaging 30.19 per cent. of iron.

**Iron Ore in Italy.**—A company has been formed for the exploitation of the iron-ore deposits in the valley of Aosta.§ The two principal mines within the company's area are those at Larcinaz and Liconi, situated respectively 2000 and 2500 metres above sea-level. According to analyses which have been made the ores are exceedingly pure, consisting entirely of ferric oxide. Owing to the in-

\* *Engineering and Mining Journal*, vol. lxxxvii. pp. 1221-1226.

† *Engineering*, vol. lxxxvii. p. 759.

‡ *Zeitschrift für praktische Geologie*, vol. xvii. pp. 343-353.

§ *Echo des Mines*, vol. xxxvi. p. 652.

accessibility of the region, it is proposed to crush the ore at the mines and transport it through a large pipe flushed with water to Aymaville, 18 kilometres distant, where it will be concentrated and pressed into briquettes capable of direct reduction in the open-hearth.

M. Priehäusser\* describes the geology of the nickeliferous iron-ore deposits at Varallo-Sesia, in the province of Novara, and considers that the occurrence of the ore is undoubtedly due to highly basic separation in gabbro, which is characterised by extensive magmatic dissociation.

**Iron Ore in Norway.**—H. H. Smith† describes the ore deposits of Follafoss-Storfjeld in Norway, discovered in 1908. The mines in question are situated north of the Beitstad Fjord, which is a continuation of the Trondhjem Fjord. The ore is generally fine grained mixed with quartz, besides which in several places segregations of iron pyrites are met with. A number of assays show the following average results:—

	Per Cent.
Iron . . . . .	54.46
Phosphorus . . . . .	0.570
Sulphur . . . . .	0.093

The topographical conditions make it, in most cases, easy to carry out mining operations. From the point of view of export value, these iron-ore deposits are very likely the most important in Norway.

**Iron Ore in Russia.**—V. Nikitin‡ describes the geology of the Central Urals, giving details of the rocks and numerous analyses. Among the metallic ores are brown hæmatite, magnetite, iron pyrites, and a nickel-bearing serpentine.

**Iron Ore in Sweden.**—Spackeler§ reviews the geological conditions of the iron-ore regions of Sweden. The mines of the Grängesberg Company cover an area of about 4 kilometres in length and 0.5 kilometre wide. The ores occur chiefly in lenticular deposits, the thickest of which are at a depth of 100 to 150 metres. Large quantities of phosphoric ores (1 to 1.5 per cent. phosphorus) are mined here for export. Magnetite and non-phosphoric hæmatite are also found, but in much less quantity. In the mines of Gellivara, situated on the extensive moorlands of Lapland, the ore is also found in lenticular deposits, which, though much smaller, are considerably more numerous than those of Grängesberg. Phosphoric ores with 63 per cent. iron are chiefly worked, one mine only producing non-phosphoric hæmatite. The Kirunavara deposits form the ridge of the range of hills of that name, and consist of magnetite with which

\* *Zeitschrift für praktische Geologie*, vol. xvii. pp. 104-116.

† *Mining Journal*, vol. lxxxvi. pp. 325-326.

‡ *Mémoires du Comité géologique*, No. 22.

§ *Glückauf*, vol. xlv. pp. 473-481, 509-515, 545-550, 594-603, 632-638, 669-672.

apatite is very intimately mixed. All the mines here are worked open-cast, and very little investigation has hitherto been made as to the continuance of the ore to depth.

**Iron Ore in Switzerland.**—W. Hotz \* estimates the iron-ore deposits at Gonzen (St. Gall) as 1,000,000 tons, the oolitic deposits at Erzegg and Planplatten containing nearly 700,000 tons, and those at Chamoson from 300,000 to 400,000 tons. Oolitic ore containing up to 35 per cent. of iron is found at the Guppenalp, at Lake Klöntal, at Glärnisch, Windgälle, Erzhubel, in the Urbach valley, and at Rüti. On the northern slopes of Val Tisch, at 2000 metres above sea-level, the Trias contains a network of hæmatite veins containing 95 per cent. of ferric oxide; and a similar deposit occurs on the ridge between Val Tisch and Val Plazbi. The old workings at Mount Chemin are estimated to contain about 100,000 cubic metres of ore with 50 per cent. of iron. In the Averstal are several old workings, the most important being at St. Martin, where the deposit of siderite and hæmatite runs to 5 metres in thickness, and contains 54 per cent. of iron, the ferruginous quartzite at the Fianell mine in the same valley yielding 21·8 per cent. of iron. The total quantity of recoverable iron in these deposits is estimated at about 2,500,000 tons.

**Iron Ore in Canada.**—W. E. Anderson † reports that what is considered to be the largest iron deposit in Canada has been discovered in Gloucester County, New Brunswick. It is estimated that there are about 20 million tons of hæmatite ore, carrying 53 to 55 per cent. of iron.

J. E. Woodman ‡ reports on the iron-ore deposits of Nova Scotia. The geographical relations of the deposits, their mineralogy and geology, are dealt with. He also gives a detailed description of the various deposits, with analyses of the ores, records of boreholes and geological sections, and other data.

W. H. Collins § reports on the occurrence of hæmatite ore in the Gowganda mining division, Ontario. Specular and kidney ore are known to exist a short distance east of Nest Lake. Specimens of the ore prove it to be of excellent character, with little admixture of silica or foreign matter. Specular ore also occurs in the basal conglomerate of the Huronian series, filling the interstices between the pebbles where an original cement was deficient. At the south end of Kenisheong Lake the conglomerate appears at the water's edge, and the hæmatite may be observed near the shore. The same thing occurs at the narrows on Duncan Lake, just south of the central expansion.

F. Hille || describes the iron-ore deposits in the districts of Thunder

\* *Zeitschrift für praktische Geologie*, vol. xvii. pp. 29–34.

† *Board of Trade Journal*, vol. lxxv. p. 280.

‡ *Canada, Department of Mines*, Ottawa, 1909.

§ *Geological Survey of Canada*, Report No. 1075, p. 45.

|| *Canada, Department of Mines*, Ottawa, 1908.

Bay and Rainy River, in the province of Ontario. This province contains immense deposits of ore, scattered over a very large area. They consist to some extent of a low grade magnetite. Other classes of iron ore are also found, notably the large deposits of titaniferous ore situated both east and west of Port Arthur, which could be utilised in the production of pig iron and ferro-titanium by means of the electric furnace.

A. P. Coleman \* and E. S. Moore give a detailed description of the iron ranges east of Lake Nipigon, in the province of Ontario.

G. C. Mackenzie † deals with the iron ores of Ontario and their geological distribution. A brief account is also given of the iron-ore mines in operation in the province.

It is stated ‡ that extensive magnetic iron deposits have been discovered near the mouth of Campbell River, on the east of Vancouver Island. Hoffman reports the existence of samples containing 67·47 per cent. magnetite.

E. Kraynik § continues his account of the tour of the Canadian Mining Institute in 1908, and describes the principal occurrences of iron ore and other minerals in Canada.

The existence of immense iron-ore deposits at Wabana, Newfoundland, has, it is stated, || been definitely established. It is estimated that the deposits aggregate at least 100,000,000 tons.

**Iron Ore in India.**—Sir T. H. Holland ¶ states that Indian iron ores are now little used. They are widely distributed, the chief ore being a quartz schist with layers of iron oxides. It is generally siliceous and of low grade. In speaking of the Mayurbhanja ore he says that one boring gave a core of 120 feet of solid ore containing 68 per cent. of iron.

In another account \*\* of these deposits it is mentioned that in the states of Mayurbhanja, Orissa, about 200 miles distant from Calcutta, three large beds of hæmatite iron ore have been discovered of which only the one at Gurumaishini will at present be exploited. In this locality there are in sight some 20,000,000 tons of ore on various ridges, analysing as follows:—

	Iron.	Silica.	Sulphur.	Phosphorus.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Sundal Ridge . . . . .	63·47	2·60	0·023	0·028
Rangamatia Ridge . . . . .	59·20	4·10	0·014	0·087
Tulla Ridge . . . . .	66·13	1·17	0·016	0·054
East of Rangamatia . . . . .	67·60	0·60	0·038	0·017

\* *Annual Report of the Bureau of Mines*, Toronto, vol. xvii. pp. 136-189.

† *Ibid.*, pp. 202-225.

‡ *Colliery Guardian*, vol. xcvi. p. 880.

§ *Glückauf*, vol. xlv. pp. 915-922, 959-969, 995-1005, 1085-1090.

|| *Iron and Steel Trades Journal*, vol. lxxxiv. p. 543.

¶ *Sketch of the Mineral Resources of India*; Calcutta, 1908.

\*\* *Iron and Coal Trades Review*, vol. lxxix. p. 464.

**Iron Ore in the Transvaal.**—A report has been published \* on the principal deposits of iron ore in the Transvaal, which are likely to be of economic importance in the future.

**Iron Ore in China.**—Deposits of iron ore are known to exist in south-eastern Manchuria, the development of which will probably contribute to the growing demands of Japan for iron.†

**Iron Ore in Korea.**—It is reported that there are extensive deposits of iron ore, principally hæmatite, in Korea, but little is known of their actual economic importance. It is thought by experts that Korea will become ultimately an important source of iron ore.‡

**Iron Ore in Siberia.**—W. Hotz§ reports on deposits of magnetic iron ore in the Altai district, on the Abakan river (where about 1000 tons per annum are won by open-cast working), and others (not worked) at Targa and on the river Teilbesse. There are numerous deposits of brown and red ironstone, as pockets and small beds in the Devonian, at Salairsk and Arinitheff. Argillaceous sphaeroidite is found associated with coal in the northern extension of the Kusnezsk coal basin.

**Iron Ore in Algeria.**—M. Clère|| describes the iron-ore resources of Algeria. A highly mineralised region occurs in the Ouenza country. Ouenza itself is a high mountain, on one side of which outcrops an immense bluff of hæmatite absolutely honeycombed by old Roman workings. It is of the best quality, grades containing 70 per cent. of iron not being exceptional. In places the ore carries from 2 to 8 per cent. of copper. The deposits are estimated at 50,000,000 to 70,000,000 tons, while 15 miles farther south, at Bou Khadra, even larger supplies, estimated at 100,000,000 to 150,000,000 tons, lie idle, for the most part owing to political exigencies.

**Iron Ore in German East Africa.**—C. Gagel¶ reports the occurrence of extensive deposits of iron ore (magnetite) in the Livingstone hills, the Likawa hills, and the Uluguru hills, the latter deposits being, however, rich in titanitic acid. Thick beds containing spathic iron ore with 48 per cent. of iron are found in the Carboniferous sandstone to the south of Ruhuhu, eastward of Nyassa. Owing to the absence of transport facilities the deposits have little value at present.

**Iron Ore in Morocco.**—Melilla is built on a point projecting into the sea, and forms the back of a triangle which rises up steeply from

\* *Iron and Coal Trades Review*, vol. lxxix. p. 549.

† *Mining Journal*, vol. lxxxv. p. 645.

‡ *Ibid.*

§ *Zeitschrift für praktische Geologie*, vol. xvii. p. 268.

|| *Engineering and Mining Journal*, vol. lxxxviii. pp. 460-463.

¶ *Glückauf*, vol. xlv. pp. 1029-1033.

the coast. At the base of this triangle, 18 miles to the south-west of Melilla, at an altitude of 2500 feet, is Djebbet Youksen, one of the richest mountains of iron ore in Africa. A railway had just been completed for the transport of ore to the coast when the disturbances broke out which led to the Spanish campaign in Morocco.\*

**Iron Ore in Northern Nigeria.**—According to W. R. Dunstan† the iron ores of Kabba, Northern Nigeria, belong to two classes, namely, fairly rich limonites, containing on an average the equivalent of about 50 per cent. of iron, and siliceous magnetites, generally containing not more than 45 per cent. of iron, and from 40 to 50 per cent. of silica. The examination of the limonite from Kao shows that it is of fair quality, containing about 56 per cent. of iron. The phosphorus is, however, too high to permit of the ore being used in the manufacture of steel except by a basic process. The ore is, nevertheless, used by the natives of the Koro country for the manufacture of iron.

**Iron Ore in Tunis.**—M. Clère‡ points out that the last fifteen years have seen the development of French North Africa as an important mining country. In Tunis the chief mine is Djebel Djerissa, near the Algerian boundary. It belongs to the company of Mokta-el-Hadid, which controls most of the ore supplies of North Africa. The ore is a stratified deposit, 40 to 52 metres thick, and contains on an average 56 per cent. of iron and 2 per cent. of manganese. The known reserves are 15,000,000 tons. Near Djebel Djerissa are Djebel Sлата and Djebel Hamelma, belonging to the same company, and containing about 11,000,000 tons of ore, with 58 per cent. of iron and 1·16 per cent. of manganese and a little lead. There is also a third region in Tunis—that in the Nefzas country, where about 4,000,000 tons of ore, rich in iron, and containing no sulphur, but a little arsenic, have been located.

**Iron Ore in Brazil.**—G. E. Anderson§ states that as the result of an examination of iron-ore deposits in Minas Geraes fifty-two outcroppings of ore have been surveyed, which averaged from 60 to 75 per cent. pure iron, free from all impurities which might interfere with its proper smelting. Nine of these outcroppings of average size and quality were carefully surveyed and measured; and it was calculated that there are about 1,000,000,000 tons of high-grade ore on or near the surface, and in situations that will permit of easy working and economical handling. On the basis of the surveys made the fifty-two deposits contain about 6,000,000,000 tons of ore. In addition, loose high-grade ore was found in quantities as large as those present in the outcrops; the total ore that is calculated to be available thus amounting to 12,000,000,000 tons.

\* *Bulletin of the American Iron and Steel Association*, vol. xliii. p. 103.

† *South African Engineering*, vol. xii. pp. 5-6.

‡ *Engineering and Mining Journal*, vol. lxxxviii. pp. 460-463.

§ *Ibid.*, p. 81.

In a report on the mineral resources of Brazil,\* compiled by the British Legation in that country, it is pointed out that the native iron ores are practically undeveloped, although Brazilian ore gives 60 per cent. of iron. The beds are said to be the largest in the world; but freight rates are too high for export purposes, and there is not sufficient fuel for smelting the iron in the country. This situation would be completely changed by the perfection of the processes of electric smelting, as Minas Geraes, like almost every State in Brazil, has abundant water-power.

**Iron Ore in Chili.**—Iron ore is very generally distributed throughout Chili, being most abundant in the northern part. An ironworks is being erected at Corral, in the province of Valdivia, for the production of pig iron for home consumption. The principal deposits are near Taltal and Capiapo, while the iron mines of Vallenar and Freirina are considered inexhaustible.†

A. Russell ‡ refers to the iron-ore deposits of Chili, and points out that the high percentage of phosphorus and sulphur in the most accessible ores accounts for the fact that up to the present iron has not been produced on a commercial scale in Chili.

**Iron Ore in Mexico.**—Most of the Mexican iron-ore deposits on both the Pacific and the Mexican Gulf sides are contact deposits, and for this reason they are limited in extent, and are likely to change to base sulphide ore in depth. A possible exception to this is the famous iron mountain of Durango. This is of good grade, but owing to the cost of bringing together the ore and the fuel, it is not likely to be utilised for some time. The Monterey iron and steel works draws its iron-ore supply from near Monclova, in Coahuila. In the south of Mexico the Oaxaca Iron, Steel, and Coal Company is developing a new coalfield, and will utilise an iron-ore deposit near the coal in northern Oaxaca. This deposit is exceptionally high grade, but has not yet been fully explored.§

**Iron Ore in the United States.**—C. W. Hayes|| gives a chemical and geological classification of the iron ores of the United States.

C. R. van Hise¶ and C. K. Leith, in reporting on the pre-Cambrian geology of North America, present a summary of the present knowledge of Lake Superior region. The rocks of the iron-bearing districts are described.

R. W. Raymond\*\* and W. R. Ingalls discuss, from a general point of view, the mineral wealth of the United States, and incidentally deal with its iron-ore resources.

\* *Iron and Coal Trades Review*, vol. lxxix. p. 621.

† *Mining World*, vol. xxxi. p. 650.

‡ *Transactions of the Mining Institute of Scotland*, vol. xxxii. pp. 13-66.

§ *Mining World*, vol. xxxi. p. 38.

|| *United States Geological Survey, Bulletin No. 394*, pp. 70-72.

¶ *Ibid.*, No. 360, pp. 108-402.

\*\* *Bulletin of the American Institute of Mining Engineers*, 1909, pp. 249-264.

During the past few years there have been developed in the Iron River, Stambaugh district, a greater number of mines than in any other portion of the old ranges. The deposits opened contain many million tons of ore. Much exploration is still in progress, with every indication that further productive mines will be discovered.\*

G. E. Edwards† states that according to the testimony of trained experts the iron-ore reserves of the Lake Superior region are practically unlimited. Of ores which assay 35 per cent. of iron and over, they estimate that there are 79,560,000,000 tons. No estimate is made of the reserves of 30 per cent. ore, the amount of which is placed at far into thousands of millions of tons. In the whole of the United States the ores grading 35 per cent. and more are estimated at 89,315,000,000 tons.

**Iron Ore in Alabama.**—G. L. Pultz‡ discusses the iron-ore resources of the Birmingham district, Alabama, and gives an account of the present development of the iron industry, and the size and situation of the chief works.

**Iron Ore in Alaska.**—A. H. Brooks§ in reporting on the mineral resources of Alaska, observes that the only iron ore which has been found is that discovered incidentally in prospecting for other minerals, and thus far it has been chiefly magnetite. It occurs in large bodies, forming contact deposits along the contacts of diorite and limestone on Prince of Wales Island. It is not impossible that Alaska may have important iron-ore reserves.

**Iron Ore in California.**—It has been known for a number of years that large deposits of iron ore exist in Lower California.|| These ores, however, have at present little commercial value, on account of their great distance from blast-furnace centres. A large majority of the deposits are well-defined fissures bursting up through the granite, and having various dips. Some of these fissures are from 100 to 200 feet wide, and almost perpendicular. The ore is of a high quality, as shown by the following analysis:—

	Per Cent.
Ferric oxide . . . . .	89.64
Ferrous oxide . . . . .	5.27
Alumina . . . . .	1.40
Silica . . . . .	1.38
Sulphur . . . . .	0.12
Phosphorus . . . . .	0.32
Manganese . . . . .	trace
Lime . . . . .	trace
Magnesia . . . . .	trace

An analysis of the blue limestone, of which there are stated to be

\* *Mining World*, vol. xxx. p. 503.

† *Ibid.*, pp. 693-694.

‡ *Engineering and Mining Journal*, vol. lxxxviii. pp. 345-348.

§ *United States Geological Survey, Bulletin No. 394*, p. 191.

|| *Iron Trade Review*, vol. xlv. p. 76.



2,000,000 tons in sight near the mines, shows 98·6 per cent. of calcium carbonate, with a trace of phosphorus.

Deposits of iron ore in Lower California are said to be extensive and of high grade, assaying up to 64 per cent. iron.\*

**Iron Ore in Georgia.**—S. M. Ball† describes the fossil iron-ore deposits of Georgia. They are similar to other Clinton ores, and were laid down in the Niagara period, one of the three subdivisions of the Upper Silurian era, and with the exception of the Oneida conglomerates, are the oldest rocks of the era. Two varieties occur in Georgia, the hard ore, and a soft ore, which is a weathered derivative of the former. A microscopic examination of thin sections of fossil shows it to consist of a calcareous matrix and the iron ore proper. In high grade ore this matrix is reduced to a minimum, but the ores vary from 40 to 80 per cent. of iron oxide, and every possible gradation appears to occur. The range and extent of the Clinton ores is very considerable, but in Georgia they are confined to five counties in the extreme north-western part of the State, namely, Dade, Walker, Catoosa, Whitfield, and Chattooga. The workable fossil ores of Dade county are confined chiefly to one ore-bed, which has an average thickness of about 3 feet, but at some points attains a thickness of 7 feet. The beds have been worked to a fair extent in Lookout Valley, but more largely in Johnson's Crook. For the most part the fossil ores of Dade county are favourably situated for working. The best ores average 53·93 per cent. of iron and 0·27 per cent. of phosphorus, and the leaner grades fall to 31·66 per cent. of iron and 0·379 per cent. of phosphorus. The Walker county deposits occur along the eastern foothills of Lookout Mountain, Pigeon Mountain, and the eastern slopes of Taylor and Dick's ridges. The ore is of rather higher grade, and the total length of outcroppings is more than 70 miles. The best ore carries 58·92 per cent. of iron and 0·475 per cent. of phosphorus, and at East Cliff station reaches as much as 59·66 per cent. of iron, with 0·40 per cent. of phosphorus. In Chattooga county the length of the outcrops is about 25 miles, and the ore is similar in its contents to that of Dade county. A variety occurs at Dirtseller Mountain, differing somewhat from the typical ore found elsewhere, as it contains more silica. The Whitfield county deposits also differ chiefly in the absence of the oolitic structure characteristic of the other ores. The phosphorus is somewhat higher. The Catoosa county deposits are well developed and of high grade.

**Iron Ores in Illinois.**—In a retrospective account of the extinct iron industry of Southern Illinois, H. E. Birkinbine‡ refers to the iron ores of the region, which correspond closely with those of Kentucky and may form a future source of supply. The ores are

\* *Iron and Steel Trades Journal*, vol. lxxxv. p. 201.

† *Engineering and Mining Journal*, vol. lxxxviii. pp. 200-204.

‡ *Iron Trade Review*, vol. xlv. pp. 247-249.

principally carbonates of the protoxide of iron, and contain iron in amounts varying from 7·7 per cent. to 43·76 per cent. A specimen from the ore banks of the abandoned Martha furnace in Hardin county yielded on analysis :—

	Per Cent.
Water . . . . .	10·8
Siliceous matter . . . . .	5·0
Peroxide of iron . . . . .	80·0 = 56·02 iron.
Alumina . . . . .	3·7
Loss and alkalis . . . . .	0·5

**Iron Ore in New York.**—D. H. Newland \* discusses the origin, formation, distribution, and resources of the Clinton ores of New York. The Clinton strata of that State are restricted to a single belt extending from the eastern central part of the Niagara river, which it crosses, to some distance into the province of Ontario, the New York section having a length, east and west, of 225 miles, and a maximum width of 5 miles. The character of the sediments as a whole shows progressive change from the conglomerates and sandstones that make up the lowest members, to finer sands and muds prevailing in the Clinton and Rochester formations, and lastly, to the limestones and dolomites which predominate in the upper formations. The Clinton beds throughout the State have a low, southerly dip, in conformity with the slope of the original coastal plain on which they were laid down. The hæmatite seams attain their fullest development in the stretch of 125 miles from Eastern Oneida to Western Wayne County, the area at Clinton having been the most extensively mined. There are two seams here, the "red flux" or fossil bed, and a lower oolitic bed. The fossil ore, which contains little more than 20 per cent. of iron, is too lean for the furnace. The oolitic, on the other hand, contains about 40 per cent., or more, of iron. The mining operations on the Clinton belt are described, and analyses of typical ore bodies given.

W. H. Hobbs † describes the low-grade iron ore of the Salisbury district, and the theories advanced with regard to its origin.

**Iron Ore in Pennsylvania.**—W. Kelly ‡ and H. S. Chamberlain discuss the statements of J. J. Rutledge § with reference to the Clinton ore deposits of Stone Valley, Huntingdon County, Pennsylvania, the former from the point of view of their geological formation, and the latter from that of their depth. At a vertical depth of 800 feet below the surface, borings have shown the ore to be fully as rich and valuable as it is at less depths.

**Iron Ore in Tennessee.**—E. F. Burchard || reports on the iron-ore resources of the Chattanooga region. Some of the ores now con-

\* *Bulletin of the American Institute of Mining Engineers*, 1909, pp. 265–283.

† *Economic Geology*, vol. ii. pp. 153–181.

‡ *Bulletin of the American Institute of Mining Engineers*, 1909, pp. 107–108.

§ *Ibid.*, 1908, pp. 1057–1087.

|| *United States Geological Survey, Bulletin No. 380*, pp. 169–187.

sidered workable were not mined ten years ago on account of their low content of iron. It is estimated that the amount available in the district is 86,569,000 tons.

**Iron Ore in Virginia.**—According to E. C. Harder\* the Appalachian iron ores of Virginia are principally brown ore of three varieties and hæmatite of two varieties. Magnetite occurs at a few localities, associated with limestone. Ironstone is found locally as concretions in many of the shale formations. The character and geological relations of the various ores are described.

**Iron Ore in Cuba.**—C. M. Weld† describes the residual brown iron ores of Cuba, which occur as large blanket deposits, chiefly in the Mayari district, 15 miles south of Nipe Bay. Here the Spanish-American Company has sole control over 18,500 acres of ore-bearing lands, estimated to contain 500,000,000 tons of ore. A smaller deposit is at Moa Bay, where the deposits are estimated to contain approximately 350,000,000 tons. Other important deposits exist, notably those of Cúbitas, estimated at 150,000,000 tons, and those at Baracoa, estimated at 40,000,000 tons. Taking the above tonnages as reasonably accurate, the deposits enumerated would appear to amount to above 1,000,000,000 tons of iron ore, and must therefore constitute a considerable factor in any forecast as to the duration of the ore supply. The whole of the deposits possess essential characteristics in common. They occur as residual mantles of enormous superficial extent, with a thickness occasionally as great as 50 or 60 feet, but varying more commonly from 10 to 20 feet. The underlying rock is serpentine, and the ore for the greater part a homogeneous, tenaceous, clay-like material, red to yellow or brown in colour, the transition between the ore and the comparatively unaltered serpentine bed-rock being fairly abrupt. Within the clay are disseminated nodules and pellets of brown ore ranging through all the hydrated forms from limonite to turgite, hæmatite, and magnetite. The following table gives representative analyses of the ore at the four more important fields:—

	Mayari.	Moa.	Taco.	Navas.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Iron . . . . .	46·03	46·75	46·23	42·48
Silica . . . . .	5·50	1·71	2·06	3·01
Alumina . . . . .	10·33	11·60	2·16	6·12
Chromium . . . . .	1·73	1·81	2·07	2·39
Titanium oxide . . . . .	not reported	0·14	not reported	not reported
Phosphorus . . . . .	0·01	0·03	0·02	0·03
Water . . . . .	13·62	13·15	not reported	not reported

The analyses represent the ore dried at 212° F., the ore as found frequently containing from 30 to 35 per cent. of hygroscopic moisture.

\* *United States Geological Survey, Bulletin No. 380, pp. 215-254.*

† *Bulletin of the American Institute of Mining Engineers, 1909, pp. 749-762.*

The composition of the ores shows how closely they are connected with each other, and probably indicates common origin. The process by which they have been formed is most likely that of sub-aërial decay, as any other theory of origin involves transportation. The theory that they are derived directly from the serpentine is borne out on a comparison of their analyses with an analysis of the latter country rock as it occurs at Moa Bay.

J. F. C. Abelspies\* also describes the soft iron-ore deposits of Cuba.

**Iron Ore in Porto Rico.**—S. H. Hamilton † gives an account of the iron-ore resources of the island of Porto Rico. Topographically it consists of a main mountain mass known as the Luquillo range, mostly composed of syenetic rocks flanked by hills of porphyry which, in turn, pass into a dissected peneplain of limestone and sedimentary rocks. Ore bodies occur in the vicinity of Juncos, the ore being probably an igneous segregation from a ferric-dioritic magma which has come into contact with limestone.

**Manganese Ore.**—A. Haenig ‡ gives an account of the various manganese ore deposits throughout the world, with analytical data and statistics of production up to 1906.

**Manganese Ore in Japan.**—J. H. Snodgrass § states that manganese is found in various provinces of Japan, the largest areas being Hokkaido, Aomori-ken, and Kyoto-fu. The most important manganese mine is, however, at Owani, in the Mitsu Province, where manganite is also found. The ore is found in the mountains near the top, close to the surface, and is transported to the sea-coast by coolies.

**Manganese Ore in Brazil.**—There are two distinct classes of deposits of manganese ores in Brazil, those in which the mineral is associated with iron ore and limestone, and those where it occurs in gneiss. To the former category belong the deposits in Miguel Burnier and Ouro Preto, and in Corumba. The Miguel Burnier ore contains about 55 per cent. of manganese, and is comparatively free from phosphorus.||

**Manganese Ore in the United States.**—T. L. Watson ¶ describes the manganese ore deposits of Northern Georgia. The ore occurs only in the form of oxides, of which the commonest are pyrolusite and psilomelane. It is of a dark blue steel colour, and much of it is crystalline. Oxides of iron and manganese are often found admixed

\* *Iron and Coal Trades Review*, vol. lxxviii, p. 1602.

† *Engineering and Mining Journal*, vol. lxxxviii, pp. 518-519.

‡ *Berg- und Hüttenmännisches Jahrbuch*, vol. lvii, pp. 121-167.

§ Consular report; *Mining World*, vol. xxx, p. 790.

|| *Zeitschrift für angewandte Chemie*, vol. xxii, pp. 321-322.

¶ *Mining World*, vol. xxx, pp. 643-644.

in different proportions in the same bed, and large deposits of limonite ore occur in close relation with the manganese ore. Between the two extremes of pure iron ore and pure manganese ore all gradations in the admixture of the two oxides are found.

E. C. Harder\* reports on the manganese deposits of Virginia, Tennessee, South Carolina, and California. The average grade of the domestic ores is much lower than that of the imported ore. Virginia, of all the States, is by far the largest producer of manganese.

S. M. Ball† describes the manganese ore deposits of Virginia. The composition of ore from the Crimora mine is shown to be: manganese, 57.29 per cent.; iron, 0.37 per cent.; phosphorus, 0.07 per cent.; while manganiferous iron ore from the northern portion of the valley of Virginia gave on analysis the following: fine ore, manganese, 52.69 per cent.; iron, 2.32 per cent.; phosphorus, 0.32 per cent.; silica, 2.79 per cent.; lump ore, manganese, 53.65 per cent.; iron, 1.53 per cent.; phosphorus, 0.32 per cent.; silica, 1.95 per cent. Analyses of manganiferous iron ore from Botetourt county showed the following composition: manganese, 24.7 per cent.; iron, 29.1 per cent.; phosphorus, 0.13 per cent.; silica, 7.7 per cent.

**Chrome Iron Ore.**—J. A. Dresser‡ describes the origin and character of the chrome iron deposits of the serpentine belt of Southern Quebec. It is indicated that these ores have originated by primary segregation from the peridotite magma. Chromic iron consists theoretically of an equal number of molecules of chromic and ferrous oxide, answering to the formula  $\text{FeO}, \text{Cr}_2\text{O}_3$ ; but ore of such purity has not been found in nature, except in meteorites. Alumina and magnesia seem to be invariably present, replacing the  $\text{Cr}_2\text{O}_3$  and the  $\text{FeO}$  in varying proportions. The following two analyses of specimens are regarded as typical of the Quebec deposits. They are from the township of Bolton, in the county of Brome, a locality which, although it has not yet produced ore on a commercial basis, seems likely to do so with proper development. Two further analyses of chromite, one from Turkey, the other from New Caledonia, are also given for comparison.

	Quebec.		Turkey.	New Caledonia.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Chromium trioxide . . .	45.90	49.75	51.70	55.70
Alumina . . . . .	3.20	11.30	14.10	16.20
Ferrous oxide . . . . .	35.28	21.28	14.20	16.20
Manganous oxide . . .	15.03	18.13	14.30	9.80

\* *United States Geological Survey, Bulletin No. 380, pp. 265-277.*

† *Engineering and Mining Journal, vol. lxxxvii. p. 1056.*

‡ *Canadian Mining Journal, vol. xxx. pp. 365-367.*

F. Cirkel \* describes the chrome iron-ore deposits of the eastern townships, Province of Quebec, Canada. He describes in detail the origin and composition of chrome iron ores, the determination of the value, and the uses of chromium.

**Molybdenum.**—A. Hasselborn † states that the abandoned Kristineborg mine, at Lerjordfald, Norway, contains a vein of molybdenum glance, 2 to 3 centimetres thick, with a length of about 100 metres along the line of strike. The adjoining Lars-Nilsa mine contains similar ore, but mostly disseminated in quartz.

**Tungsten.**—T. L. Walker ‡ reports on the tungsten ores of Canada. The known occurrences of tungsten ores throughout the world are comparatively few, which lends additional interest to some discoveries of scheelite which have been made within the past year or two in Nova Scotia. The several occurrences of tungsten ore in Canada are described in detail, and a general statement is given on the geological occurrence of the ores, chemical tests, concentration, the uses of the metal, producing mines of other countries, and statistics of the world's production.

F. L. Hess § reports on the tungsten deposits of South Dakota. In this region wolframite is the form in which the tungsten ores chiefly occur.

In his description of the tungsten ore deposits of Argentina, O. von Keyserling || mentions wolframite and scheelite as the principal ores, frequently accompanied by mica and tourmaline. The occurrence being chiefly in the form of pockets, which diminish in richness with the depth (except, perhaps, at Los Condores), the economic value of many of the deposits is regarded as problematical.

The occurrence and utilisation of tungsten ores are dealt with ¶ in detail.

**Vanadium.**—D. F. Hewitt \*\* describes the occurrence of vanadium deposits in Peru, and refers incidentally to the bibliography of the occurrence of vanadium compiled by F. W. Clarke †† and that of H. Moissan. ‡‡ The Peruvian deposits described are two in number, the most important being at Quisque (Minasraqua), in the province of Pasco, and the less important at Yauli, in the province of Tarma. The former is accessible by horseback, but the Central Railway of Peru passes through the latter district. As the deposits at Yauli throw some light on those of the Quisque district, they are described

\* *Canada, Department of Mines*, Ottawa, 1909.

† *Montan Zeitung*, vol. xvi. p. 234.

‡ *Canada, Department of Mines*, Ottawa, 1909.

§ *United States Geological Survey, Bulletin* No. 380, pp. 131-163.

|| *Zeitschrift für praktische Geologie*, vol. xvii. pp. 156-165.

¶ *Bulletin of the Imperial Institute*, vol. vii. pp. 170-184.

\*\* *Bulletin of the American Institute of Mining Engineers*, 1909, pp. 290-316.

†† *Geological Survey of the United States, Bulletin* No. 330.

‡‡ *Chimie Universelle*, vol. iii.

first. Although the presence of vanadium in the so-called anthracite (asphaltite) of the Yauli region was only described in 1894 it was known as far back as 1892. The veins of asphaltite occur in a well-defined belt in the sedimentary rocks, and have been found over a distance of fifteen miles. The veins occur as lenses, varying from 0.5 inch to 22 feet in width, and having a maximum known length of about 500 feet. The asphaltite is black, lustrous, and softer than ordinary bituminous coal. Analyses are given, showing that the ash varies from 0.98, with 0.86 per cent. of vanadic oxide, to 46.9 per cent., with 0.67 per cent. of vanadic oxide. There does not appear to be any relation between the amount of ash and that of the vanadic oxide present, and the sample highest in the latter constituent (1.40 per cent.) corresponds to an ash percentage of only 6.27. The occurrence of vanadium in the Quisque district was discovered by a party of Indians late in the year 1905, during a search for coal. The vanadium deposit occurs entirely within a red shale, in Jura-Trias and Cretaceous formations similar to those of Yauli. The geology of the region is described and illustrated by means of diagrams. Here again the vanadium deposit is a lens-shaped mass composed principally of three constituents: quisquite, a black, lustrous hydrocarbon; coke, a black vesicular hydrocarbon containing granules of quisquite; and patronite, a greenish-black mineral called after A. R. Patron, who first recognised the mineral as containing vanadium. An analysis of these minerals shows the latter to contain as much as 19.53 per cent. of vanadium, with 54.29 per cent. of combined sulphur and 4.5 per cent. of sulphur soluble in carbon bisulphide. Some samples of the pure material have been shown to contain 24.8 per cent. of vanadium, and patronite may be regarded as a vanadium sulphur compound, which can best be represented by the formula  $V_2S_6 + Sn$ . Photomicrographs of the mineral are given and a theory of its formation suggested. Two minerals of approximately definite composition have been found upon the surface, and have been described respectively as red oxide and green oxide. The red oxide occurs typically as a globular aggregate with a radiated structure, although amorphous specimens are common. It contains 67.60 per cent. of vanadic oxide and 2.82 per cent. of molybdic oxide. A brownish oxide is also found in irregular masses. This oxide has the peculiar property of swelling and disintegrating in water. At a depth of 8 to 10 feet from the surface a greenish-black mineral is found, containing 57.33 per cent. of vanadic oxide and 3.28 per cent. of molybdic oxide. It also contains 4.76 per cent. of hypovanadic oxide ( $V_2O_4$ ). The occurrence of vanadium in asphaltites appears to depend upon three factors: (1) its dissemination as an oxide in a rock of a fair degree of porosity; (2) impregnation with a hydrocarbon; and (3) the presence of sulphur, or sulphurous vapours. In Peru the first of these conditions undoubtedly exists over large areas, while the two remaining conditions have been brought about by the intrusion of dykes. It would therefore seem a safe forecast to predict that most asphaltites containing more than 2 per cent. of sulphur will also contain vanadium.

H. E. Ede\* describes the occurrence and uses of vanadium. Although widely distributed, the mining of vanadium ore is almost entirely confined to certain parts of Spain, one well-defined district in Peru, and several of the States in the United States. Other localities where it occurs in small quantities are Mexico, France, Portugal, and a few isolated districts in Great Britain.

H. Fleck† describes the occurrence of vanadium in Colorado. The Placerville deposits carry vanadium in such quantities and are so extensive that they are likely to become an important source of this metal. The process of extraction of the metal from the ores is described.

K. A. Nenadkevitch‡ has found in the uranium and vanadium mines close to the Alai Mountains, and south of Andijan, Siberia, the following new vanadium minerals: (1) Turanite, which is a copper vanadate, and occurs in compact or spongy form, or as radio-spheroidal aggregates; and (2) alaite, which is a hydrated vanadium pentoxide, and occurs in thick soft mossy masses, having a blood-red colour and a silky lustre.

Katzer§ gives a list of the principal vanadium ores and a short account of the occurrence and characteristics of those richest in vanadium.

E. Weckwarth|| describes the occurrences in Peru of cerium, molybdenum, tellurium, titanium, tungsten, and vanadium. Vanadium sulphide ore was discovered in 1906 near Quisque, and near the deposit are extensive earthy masses of various colours whose content of vanadic acid rises to 30 per cent. These are undoubtedly products of oxidation of the sulphide ore, and they probably constitute new species. Vanadiferous coal also occurs in Peru with a percentage of 0.456 vanadium.

The occurrences of vanadium, tungsten, bismuth, nickel, and cobalt in Mexico are reported upon. The Mexican field has as yet been but slightly investigated for these special minerals.¶

**Meteorites.**—W. F. Denning\*\* describes a specimen of a meteorite sent from the Wanganui observatory. In the aerolitic fall of the 26th November 1908 two pieces weighing respectively  $4\frac{1}{2}$  lbs. and 3 lbs. were secured. The specimen consists of dark grey stone or admixture of stone and iron, which has evidently undergone intense heat and is of a crumbly nature. The analysis is being made at Wanganui.

G. P. Merrill †† has averaged some ninety-nine trustworthy analyses

\* *Mining Journal*, vol. lxxxvi. pp. 419-421.

† *Colorado School of Mines Quarterly*; *Mining World*, vol. xxx. pp. 396-398

‡ *Bulletin de l'Académie de Science*, St. Petersburg, 1909, pp. 185-186; *Journal of the Chemical Society*, vol. xcvi., Part II. p. 411.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lvii. pp. 411-412.

|| *Mining Journal*, vol. lxxxv. p. 523.

¶ *Mining World*, vol. xxxi. p. 11.

\*\* *Nature*, vol. lxxx. p. 128.

†† *American Journal of Science*, vol. xxvii. pp. 469-474.



of stony meteorites, and has compared the result with the average composition of the rocks of the earth's crust, with the result that the stony meteorites are found to be much more basic in composition than the latter.

## II.—IRON ORE MINING.

**Shaft-sinking.**—F. W. Adgate\* describes the methods employed in sinking through quicksand at iron-ore mines on the Marquette range, and in the subsequent lining of the shafts with concrete.

**Explosives and Blasting.**—J. A. Holmes† enumerates the explosives which have passed the new test requirements of the United States Government, and are consequently to be termed permissible explosives. A description of the method of testing will be published by the Geological Survey Department.

The requirements of the United States Government with regard to the manufacture of various explosives used in mining operations have been published‡ and a list is given of the permissible explosives.

A. L. Hodges§ describes the composition of the explosives most commonly in use for blasting purposes.

H. M. Thomas|| deals with the theory of blasting by means of high explosives. The real crux of effective breaking is to ascertain the tendency of the country rock to break more easily in one direction than in any other, or in other words, to find the grain of the rock. The mode of doing this and the position of blasting charges so as to give the most efficient breaking results are considered, and illustrated by means of diagrams.

E. H. Vaughan¶ gives the following method by which he improvises detonators, when without means of obtaining a supply for a considerable time. In a tube of paper, at the bottom, one inch of loose dynamite was tamped, and above this 1½ inch of an intimate mixture of 30 grammes of potassium chlorate, 7 grammes of sulphur, 5 grammes of white sugar. An ordinary Bickford fuse was inserted, and the whole secured with twine. Inserted in the borehole with the dynamite this gave the same rending effect as an ordinary detonator.

**Rock-drills.**—W. L. Saunders\*\* describes the process of driving headings in rock tunnels with special reference to the various machines employed in European and American practice. The machines dealt

\* *Iron Age*, vol. lxxxiv. pp. 622-624.

† *Mining World*, vol. xxx. p. 1016.

‡ *Canadian Mining Journal*, vol. xxx. pp. 363-364.

§ *Mining World*, vol. xxxi. pp. 501-502.

|| *Engineering and Mining Journal*, vol. lxxxviii. pp. 349-352.

¶ *Mining Journal*, vol. lxxxvi. p. 93.

\*\* *Bulletin of the American Institute of Mining Engineers*, 1909, pp. 337-363.

with are the Burleigh drill carriage; the Karns machine; the Radialax, which has been used in collieries; the Proctor; Sigafoss; Fowler; and Benneto machines.

O. Schueller\* describes the construction and method of working of the Brandt, the Ingersoll, the Mayer, and the Siemens-Schuckert rock-drills. The efficiency and power requirements of these are considered.

In a thesis presented to the Colorado School of Mines, H. A. Everest† gives records of thirty different types of rock-drilling machines.

G. Ölwein‡ describes the Davis-Calyx hollow rock-drill, the bits of which are of the Davis type and are not fitted with diamonds.

C. M. Haight§ describes a method of dealing with a breakage that occurred while putting in a diamond drill-hole at Rockland, Michigan.

Comparative records of costs in drilling rock by means of electrically controlled air drills have appeared.||

**Deep-boring.**—An account is given¶ of the boring of the deepest diamond drill-hole ever put down in the North American continent. It was bored in connection with exploratory work on the Marquette iron range. A depth of 3265 feet was attained. Six months' steady work was required before the task was accomplished, and the utmost care was necessary in the last thousand feet. A surprisingly small amount of equipment and material was used in boring the hole.

**Methods of Working.**—The methods of mining iron ore in the Swedish iron-bearing districts are described at length by Spackeler.\*\*

A new form of transporter which has been in use for about two years at the mines of Lloyd's Ironstone Company, near Kettering, consists of a large wheel about 80 feet in diameter, of similar construction to a cycle wheel, and driven by a cotton rope running in a groove under the rim of the wheel. Projecting from the rim is an annular table, 3 feet 6 inches wide, which receives the load of earth from a mechanical hopper, and carries it round to the opposite side, when it is pushed off by a scraper on to the spoil bank. This scraper can be adjusted to any point of the circumference without stopping the wheel, thus effecting a more uniform distribution of the earth. By means of this transporter the overburden is removed from the mine, and carried across the line of rails on which the trucks for transporting the ore run, and the process is reversed when it is required to replace the land for agri-

\* *Zeitschrift des oesterreichischen Ingenieur- und Architekten Vereines*, vol. lxi. pp. 137-142, 153-156, 169-172.

† *Mining and Metallurgical Journal*, vol. xvi. p. 4.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lviii. pp. 364-366.

§ *School of Mines Quarterly*, vol. xxx. pp. 98-99.

|| *Engineering Contracting*, April 7, 1909; *Engineering and Mining Journal*, vol. lxxxviii. pp. 310-311.

¶ *Mining World*, vol. xxxi. p. 212.

\*\* *Glückauf*, vol. xlv. pp. 473-481, 509-515, 545-550, 594-603, 632-638, 669-672.

cultural purposes. The wheel is designed to deal with half a hundred-weight of load per linear foot of table.\*

**Mine Surveying.**—B. S. Lyman† points out the need of instrumental surveying and mapping in geological surveys. The neglect of complete topographical mapping and the plotting of cross-sections that may properly take into account the varying course of rock-beds and their elevation may lead to serious error, an instance of which is given.

D. Harrington‡ describes the method used in the Rocky Mountain region for surveying and mapping surface work.

T. E. Fisher§ shows methods of plotting maps of underground workings. Maps should be kept in such condition as to enable the amount of ore broken each month and the rate of development to be readily calculated by the surveyors.

E. Doležal|| has given a general account of mine surveying.

**Handling Iron Ore.**—L. Schütt¶ gives an illustrated description of an arrangement for filling an ore-bin at the works of the Société Anonyme des Hauts Fourneaux & Fonderies de Pont-à-Mousson (Meurthe et Moselle) in France. The quantity of ore dealt with is 180 tons per hour. A travelling bridge spans the bin, and tubs from the shaft are emptied into a filling funnel, which shoots the ore into self-discharging bogies.

A. Gradenwitz\*\* gives an illustrated description of an aerial ropeway for the transportation of iron ore from an extensive deposit below Mount Canigou in the Pyrenees. The ore is taken by the ropeway either to Port Vendre on the Mediterranean for shipment abroad, or is carried to the railway for conveyance to the works of Schneider & Co., Le Creusot.

An illustrated description is given†† of the ore-handling bridge at the works of the Carnegie Steel Company, Duquesne, Pennsylvania. The bridge has a span of 230 feet, with a cantilever extension of 65 feet at either end. It spans an ore-yard of about 1800 feet in length, serving six large blast-furnaces, and has a capacity of 600 tons per hour.

**Economics of Mining.**—Spackeler‡‡ refers to the effect upon the iron industry of Germany of the agreement concluded in Sweden in 1908 between the Swedish State and the Kirunavara-Luossavara, the Gellivara and the Grängesberg-Oxelösund Transport

\* *Engineer*, vol. cvii. pp. 638-639.

† *Bulletin of the American Institute of Mining Engineers*, 1909, pp. 667-674.

‡ *Mines and Minerals*, vol. xxx. pp. 94-97.

§ *Mining World*, vol. xxxi. pp. 121-122.

|| *Berg- und Hüttenmännisches Jahrbuch*, vol. lvi. pp. 193-212, 331-344.

¶ *Stahl und Eisen*, vol. xxix. pp. 504-507, 546-550.

\*\* *Engineering and Mining Journal*, vol. lxxxvii. pp. 1119-1121.

†† *Ibid.*, pp. 944-945.

‡‡ *Glückauf*, vol. xlv. pp. 473-481, 509-515, 545-550, 594-603, 632-638, 669-672.

Companies with respect to the working of the iron-ore deposits in northern Sweden. Under the terms of the covenant the State is precluded for twenty-five years from exporting any of the ore raised from the mines in that region, and is restricted to supplying ore solely for home consumption. The only mines at which iron ore for export may be worked are those belonging to the three above-named companies in Lapland and central Sweden. No development of the northern mines under State control on any considerable scale is therefore to be anticipated before 1933, and it is highly problematical whether any change in the economic conditions will even then be made.

M. C. Little\* has published a synopsis of the mining laws of Mexico.

**History of Iron Mining.**—A bibliography for 1906 and 1907 of North American Geology has been compiled by F. B. Weeks † and J. M. Nickles.

### III.—MECHANICAL PREPARATION.

**Grading Ores.**—A. O. Christensen ‡ discusses the phenomena attending the free and hindered settlement of mineral grains and the theory and principles underlying such action. Numerous equations, curves, and diagrams are given for ascertaining rates of subsidence of minerals, worked out from experimental data and from theoretical considerations, the results of which, checked and rectified by actual practice, can be applied to the problems involved in the grading and classification of ores.

**Iron Ore Dressing.**—F. Rigaud § describes modern practice in the mechanical preparation of ores.

A description has appeared || of the Hennig ore concentrator.

A new ore-separator designed by A. and K. Wård is described. ¶ The separator is centrifugal, and the separation is due to the different specific gravity of the materials treated.

**Magnetic Separators.**—S. R. Stone\*\* deals with the use of magnetic separators for separating iron products from sand, slag, coke, coal, brass, scrap, and other non-magnetic materials.

To concentrate 32 per cent. iron ore to 62 per cent. a magnetic ore-separator is used in Sweden, †† which consists of a short conical drum

\* *Mining World*, vol. xxxi. pp. 25-27.

† *United States Geological Survey, Bulletin No. 372.*

‡ *Engineering and Mining Journal*, vol. lxxxviii. pp. 503-509.

§ *Echo des Mines*, vol. xxxvi. pp. 845-846.

|| *Canadian Mining Journal*, vol. xxx. pp. 213-214.

¶ *Bihang till Jernkontorets Annaler*, 1909, pp. 414-417.

\*\* *American Machinist*, vol. xxxii., Part I., pp. 688-692.

†† *Mining World*, vol. xxx. p. 542.

of non-magnetic material revolving on a horizontal axis, and fitted inside with a number of pieces of iron separated from one another by cement. Under the drum are three electro-magnets, connected so that the two outer ones are of like polarity. As the pieces of iron within the drum approach the magnets they become magnetised, and attract the iron of the finely divided ore fed into the drum. The attracted ore is carried round a certain distance, and then falls off on to a sheet of metal projecting into the drum, whence it is washed off by a stream of water on to an endless-belt conveyor.

E. Ferraris \* describes the process of the magnetic preparation of iron ores at Montepioni.

H. E. Wood † points out the difficulties of separating tungsten minerals by the wet concentration process, and discusses the advantages and disadvantages of the magnetic separation of tungsten ores.

**Briquetting Iron Ore.**—N. V. Hansell ‡ states that one of the most recently erected Gröndal plants in Sweden is that connected with the Lulea Ironworks. The ore used is taken from the Gellivara mines and contains 58 per cent. of iron, 0·10 per cent. of sulphur, and 1·3 per cent. of phosphorus. Although this ore is high in iron, it was found advantageous, on account of its high phosphorus content, to fine grind it, separate it wet, and then briquette the concentrates. The latter generally contain 72 per cent. of iron with 0·017 per cent. of sulphur, and 0·008 per cent. of phosphorus.

In developing the iron-ore resources of Sydvaranger it has been decided to use the Gröndal process. The ore is a low grade magnetite and contains only 34 per cent. of iron. It is calculated that 450,000,000 tons of ore are available and that by open quarrying 1,200,000 tons yearly can be cut. A Gröndal installation capable of making 1500 tons of concentrates daily with 66 to 69 per cent. of iron is being laid down. One-third of the output will be briquetted and the remainder shipped as fine concentrates. §

Dünkelberg || discusses a new method of briquette-making with additions of molasses, fossil meal, and carnallite, which has been used with good result in the Paint Works of Meister, Lucius & Brüning, at Höchst-on-Main, to recover the ferriferous residues and sandy waste of the aniline manufacturing process.

#### IV.—METALLURGICAL PREPARATION.

**Ore-roasting Furnaces.**—A. P. Hachtmann ¶ describes a kiln in which pulverised fuel is used as fuel for nodulising fine iron ores.

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lvii, pp. 467-470.

† Paper read before the Colorado Scientific Society; *Mining World*, vol. xxx. p. 968.

‡ *Engineering and Mining Journal*, vol. lxxxvii. p. 909.

§ *Iron Age*, vol. lxxxiv. p. 840.

|| *Stahl und Eisen*, vol. xxix. pp. 551-552.

¶ *Chemical Engineer*, vol. ix. p. 149.

It consists of a brick-lined cylindrical steel shell, 100 feet long and 7 to 8 feet in diameter, supported on two girth rollers at a slight angle from the horizontal and rotated by means of a girth driving gear, provision being made for varying the speed of rotation. The ore is fed in at the higher end and the fuel at the lower end. The ore travels slowly down the length of the furnace, passing gradually into the maximum temperature at the lower end, where if the heat, air supply, and time are properly adjusted it will be discharged in nodules about the size of a walnut. To prevent the ore adhering to the lining, it must be heated by radiation and not by a flame which impinges on the ore and furnace lining. Pulverised coal and the method of burning it have the advantage over producer gas of greater ease of control. Producer gas gives a much larger flame which spreads out over the whole furnace and keeps the ore in a plastic condition longer, so that while the ore from kilns fired with powdered coal is nodular, that from producer-fired kilns has the appearance of a flat, irregular, honeycombed slab which is often brittle. The regulation of the air supply is important, especially as it effects the elimination of sulphur and arsenic in the ore, and the pulverised fuel has all the advantages in control of air supply. The efficiency of the producer gas firing is conservatively placed at about 85 per cent. of that of powdered fuel.

**Agglomeration of Fine Ore.**—J. Savelsberg \* describes a process for the sintering together of fine oxides of iron and manganese and pyrites residues. As fuel, coal or coke dust, brown-coal or peat may be used and mixed with the ore in quantities not larger than sufficient to produce the necessary heat for sintering the ores. The mixture is charged into a converter and ignited, and air is blown through until the whole of the combustible portion is burnt out. By this means the particles of ore are sintered and caked into a mass which can afterwards readily be broken to any desired size.

**Ore-Roasting.**—A process of ore-roasting by reducing the oxides by gas and afterwards dressing the ore by magnetic or other means has been patented by W. Mathesius.†

\* *Chemiker Zeitung (Repertorium)*, vol. xxxiii. p. 343.

† *Metallurgie*, vol. vi. p. 62.

## REFRACTORY MATERIALS.

**Standardisation of Refractory Materials.** — L. Baradue-Muller\* discusses the principles underlying the use and application of refractory materials in industrial operations. He traces the development of the use of refractory materials concurrently with that of metallurgical operations from the earliest times. It is since more recent times that the need for attention to refractory materials has been felt, since they are now required to withstand, not only temperatures vastly higher than those formerly employed, but also the action of liquid, solid, and gaseous bodies in contact with them. Hence greater care is required in their selection, yet empirical methods still prevail, although the need of standardisation in respect of certain qualities has already begun to make itself felt. It is time, too, that the industry of refractory materials should respond, by the institution of research and experiment, to the demands now being made by modern methods of metallurgy. Hitherto no attempt has been made to develop the industry to the extent necessary to cope with the more stringent requirements made in metallurgical operations. Much ground remains to be covered, as the subject of the behaviour of refractory materials at exceedingly high temperatures has been almost wholly neglected. This is owing to a number of causes, amongst which are the lack of technical chemical knowledge and the want of laboratories at works where refractory materials are made or prepared. For this reason, coupled with the growing need, large metallurgical concerns have been forced to create departments for the manufacture of refractory materials for their own use, whereas the industry itself should have been in a position to meet the growing requirements of the age and to profit directly by the increased demand. Already, however, there are signs that this state of things is about to yield to healthier conditions, and that the refractory material industry is being stimulated into undertaking the research work necessary to its own profitable development. It is in Germany, in particular, that this change is principally manifest, although even in that country there is a tendency to depend on old methods, instead of boldly breaking new ground and instituting new and independent methods of investigation.

Many of the directions in which experimental inquiry is needed, and should be directed, are indicated. These vary with the nature

\* *Revue de Métallurgie, Mémoires*, vol. vi. pp. 700-729.

of the refractory materials themselves, and, for the purpose of discussion, the latter are grouped into aluminium silicate products, alumina products, silica products, magnesia products, carborundum products, chromite products, and carbon products. The nature, sources, and preparation of each of these categories are passed under consideration, after which the following suggestions as to the foundations upon which a system of standardisation might be based, are given:—

The purchase of refractory materials should be made on what is called a ceramo-metric basis, which would fix their technical value by indicating: (1) their chemical composition; (2) their varying refractory resistance; (3) their absolute and apparent densities, degree of compactness or porosity, and calorific conductivity; (4) their mechanical resistance to compression and shock. This would allow of the value of a refractory product being concisely expressed by a formula of some such description as the following:—

$$V = \frac{\text{Al}_2\text{O}_3}{\text{SiO}_2 + \text{fluxes}} + \text{Cal. Res.} + \frac{\text{Abs. Dens.}}{\text{App. Dens.}} + \text{Mech. Res.}$$

which would aid in determining its industrial application.

The backward condition of the industry is referred to the following causes: (1) neglect to purify the raw materials; (2) mechanically inefficient methods of manufacture, superannuated and inadequate to the new conditions which require fulfilment; (3) preliminary calcination, or final heating carried out at temperatures much below those which will be reached in actual usage. These causes occasion (1) a fusion point below that required; (2) a lack of uniformity in the dimensions of pieces; (3) lack of compactness; (4) too great a degree of porosity to withstand the destructive action of liquid or gaseous chemical agencies; (5) insufficient mechanical strength to withstand wear by friction, shock, &c.; (6) too great a degree of sensitiveness to temperature variations to avoid the occurrence of cracks, fissures, desquamation, &c., which all help to cause mechanical and chemical destruction.

The whole of these defects could be almost entirely prevented in the case of many refractory products, and very largely obviated in others, were scientific methods to be adopted in their preparation and manufacture.

**Physical Properties of Refractory Materials.**—S. Wologdine \* has undertaken a series of investigations on the conductivity, porosity, and permeability of refractory materials, under the auspices of the Société d'Encouragement pour l'Industrie Nationale. These are the most important qualities in connection with the construction of metallurgical and ceramic furnaces, crucibles, retorts, and such-like appliances. The materials employed in the investigations were of four descriptions, namely: (1) mixtures for refractory products proper,

\* *Revue de Métallurgie, Mémoires*, vol. vi. pp. 767-806.



(2) those for porcelain, (3) faience and white ware generally, and (4) mixtures for red and brown earthenware. Tables are given showing the results of the experiments on all four classes of product.

**Faulty Firebricks.**—The defects of firebricks which shorten the life of blast-furnace linings are pointed out. The irregularities in dimensions, shape, and burning, and the means of overcoming these defects are dealt with.\*

**Fireclay.**—Before the Royal Society at Edinburgh, on March 15, 1909, J. W. Gregory † adduced evidence to show that the Glenboig fireclay was deposited in the Millstone Grit period; it contains lenticular crystals of sideroplesite, but no kaolinite, the main substance being isotropic and consisting of halloysite.

R. R. Hice ‡ describes the refractory flint clays of the Mercer group and of the Mahoning sandstone, found in Pennsylvania, and discusses the relations subsisting between clay mining and coal mining in that State.

It is stated § that an extensive deposit of fireclay has recently been discovered in Queensland, on Monduran Creek, between Gladstone and Keppel Bay.

H. E. Ashley || discusses the colloid matter of clay and its measurement. The sources and forms of the colloids, and the ageing and drying of fireclays are dealt with.

**Graphite.**—Graphite occurs extensively in Korea, and though the mining of it has hitherto been neglected, it is thought that some of the deposits can be made to furnish graphite of high grade. ¶

Numerous occurrences of graphite and graphite-bearing rocks have been reported recently from Africa, and in many cases specimens have been forwarded for report to the Imperial Institute, who have published \*\* the results of their examination.

It is stated †† that at the graphite deposits, which were recently discovered in the Pietersburg district of the Transvaal, the main reef is 7 feet in thickness, and the working shaft is in graphite on all sides for its whole distance, the bottom appearing to be solid pure graphite. A second body, 4 feet wide, has been cut into, and found to be underlying the main reef, separated from it by a layer of schistose rock. The whole body of graphite is thus about 11 feet across. At the other points where the reef is opened up, the same widths of ore body are found.

\* *Iron Age*, vol. lxxxiii. pp. 1336–1337.

† *Nature*, vol. lxxx. p. 148.

‡ *Engineering and Mining Journal*, vol. lxxxviii. pp. 105–107.

§ *Board of Trade Journal*, vol. lxxv. p. 343.

|| *United States Geological Survey, Bulletin No. 388.*

¶ *Mining Journal*, vol. lxxxv. p. 645.

\*\* *Bulletin of the Imperial Institute*, vol. vii. pp. 166–169.

†† *South African Commerce and Manufacturers' Record*, March 1909; *Board of Trade Journal*, vol. lxxv. p. 131.

H. P. H. Brumell\* describes the methods of dressing and concentrating Canadian graphite. The ore is abundantly found in the county of Labelle, in the province of Quebec, and is a graphitic schist carrying the graphite in small lenticular particles.

A description is given† of the equipment of the works of the International Acheson Graphite Company for the manufacture of artificial graphite.

**Magnesite.**—The extent of the deposit at St. Martin is estimated by F. Bondkowsky‡ as 15,000,000 tons of crude, or half that quantity of calcined magnesite. Analysis shows the magnesite to contain 41·85 to 43·59 per cent. of magnesia, 1·13 to 3·45 per cent. of lime, about 3·65 of ferrous oxide, 0·16 to 0·50 of alumina, and 1·83 to 2·30 of silica.

K. A. Redlich§ describes the magnesite deposit at St. Martin (Styria), the bulk of which, however, is too high in calcium carbonate to furnish a usable product when calcined, and various types of magnesite deposits occurring elsewhere, with typical examples.

It is stated|| that in the vicinity of the town of Atlin, British Columbia, there is a unique deposit of hydro-magnesite. Its white surface extends over two to three hundred acres, but its depth is undetermined. Its origin is believed to be due to the action of mineral springs in the magnesian rock. An analysis, showing its pure quality, is given.

It is stated¶ that the purest quality of magnesite is obtained from India. The following table is given, showing the comparative purity of the Indian and other magnesites:—

	Indian.	Styrian.	Grecian.
	Per Cent.	Per Cent.	Per Cent.
Magnesia . . . . .	47·53	42·43	47·00
Carbon dioxide . . . . .	51·44	50·41	51·00
Ferric oxide }	0·30	3·2 to 4·3	} 1·50
Alumina }	trace	1·0 to 1·7	
Lime . . . . .	0·22	0·9 to 1·93	0·50
Silica and insoluble . . . . .	0·27	...	...
Moisture . . . . .			

H. H. Dains\*\* describes the work carried on at the magnesite deposits in the Chalk Hills, near Salem, Madras Presidency. The magnesite covers an area of about 2000 acres, and occurs in numerous

\* Paper read before the Canadian Mining Institute; *Mining World*, vol. xxx. pp. 633-635.

† *Electrochemical and Metallurgical Industry*, vol. vii. pp. 187-188.

‡ *Montan Zeitung*, vol. xvi. pp. 160-161.

§ *Zeitschrift für praktische Geologie*, vol. xvii. pp. 102-103, 300-310.

|| *Iron and Coal Trades Review*, vol. lxxix. p. 307.

¶ *Iron and Steel Times*, vol. i. p. 307.

\*\* *Journal of the Society of Chemical Industry*, vol. xxviii. pp. 503-505.

irregular veins which ramify in an ultrabasic intrusion of eruptive rock called dunite, a mineral consisting essentially of magnesium ortho-silicate. The average mineral is of excellent quality, shipments during 1909 having shown 96 to 97 per cent. of magnesium carbonate, with a low percentage of lime, silica, alumina, and oxide of iron.

**Carborundum.**—An illustrated description is given \* of the equipment of the works of the Carborundum Company at Niagara Falls. The first commercial carborundum furnace, as operated in 1893, was a loosely constructed box of firebrick, consuming 75 electrical horse-power, and producing in each run about 50 lbs. of carborundum. The present furnace utilises 2000 horse-power, and has an output of 15,000 lbs. of crystalline product in each run.

A brief description of the discovery of carborundum and its manufacture is given.†

\* *Electrochemical and Metallurgical Industry*, vol. vii. pp. 189-193.

† *Canadian Machinery*, June 1909, p. 66.

## FUEL.

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## I.—CALORIFIC VALUE.

**Calorimetry.**—C. J. Emerson \* has devised a new bomb of the Berthelot type, in which the receptacle, instead of having one main portion with a cover, consists of two halves drawn together by a large nut. This design overcomes several difficulties of manipulation, and the insertion of the lining is accomplished more easily. The general principles on which the instrument is worked are practically the same as for others using oxygen under pressure.

L. Stinchfield † gives an account of experiments carried out at Worcester Polytechnic Institute, for the determination of the heat value of liquid fuels. A comparison was made of the three leading methods of experiment, using the bomb calorimeter, the Junker, and the constant-pressure apparatus.

A series of tests of the various methods of measuring the heating values of gas has been carried out at the University of Wisconsin, showing the untrustworthiness of some types of calorimeter in use. Investigation is to be continued in co-operation with the American Gas Institute and the Railway Commission.‡

F. Lichte § describes a Junker's recording calorimeter for the continuous determination of the calorific value of gases so that all variations are indicated.

\* *Journal of Industrial and Engineering Chemistry*, vol. i. pp. 17-18.

† *Journal of the Worcester Polytechnic Institute; Engineer*, vol. cviii. p. 304.

‡ *Engineer*, vol. cvii. p. 395.

§ *Giesserei Zeitung*, vol. vi. pp. 168-171.

C. E. Lucke \* describes, with illustrations, a simple continuous calorimeter for ascertaining the calorific value of fuel gas.

**Pyrometry.**—S. H. Stupakoff † deals with the types of pyrometers that are available for use in measuring high temperature in the production of malleable castings. In the author's opinion thermo-electric pyrometers offer many advantages over other types of temperature-measuring instruments, as they are simple in construction, are easily handled and applied, and can be used in numerous instances where the use of any other type of pyrometer would be impossible. The uses of pyrometers, and their application to the annealing of malleable iron, are discussed, and attention is called to errors in readings.

C. E. Foster ‡ deals with the use and application of pyrometers in foundry work. The advantages of temperature records are enumerated, and a description of various pyrometers suitable for foundry use is given.

C. H. Wilson § gives a practical note on thermo-electric pyrometers.

R. P. Brown || gives an historical review of the various methods of measuring high temperatures, and describes modern pyrometers.

C. Féry ¶ has designed a new pyrometer, which, while possessing all the advantages of the old instrument bearing his name, does not require a galvanometer and leads. Instead of the heat rays being concentrated on a thermo-electric couple, as in the earlier instruments, they are focussed by means of a concave mirror on a small bimetallic strip coiled into the form of a spiral which unrolls when heated, owing to the largely different co-efficients of expansion of the two metals composing it.

C. E. Foster \*\* also describes Féry's new radiation pyrometer, and states that at 1000° C. the accuracy is well within 2 per cent.

C. B. Thwing †† describes a new type of radiation pyrometer, the action of which is dependent upon the effect of radiation of a heated body upon a sensitive thermo-element, the current generated being measured by a galvanometer.

An illustrated description †† is given of the latest designs of thermo-electric pyrometers of the Siemens & Halske Company, for use in smelting works for measuring the temperature of the hot blast in blast-furnaces, in annealing and hardening furnaces, and foundries. Temperatures of 1600° C. can be measured, and the limit of error at the temperature of 1000° C. is about 5° C.

\* *Transactions of the American Society of Mechanical Engineers*, vol. xxx. pp. 27-38.

† *Transactions of the American Foundrymen's Association*, vol. xxviii. pp. 161-184.

‡ *Foundry*, May 1909.

§ *Electrochemical and Metallurgical Industry*, vol. vii. pp. 116-117.

|| *Proceedings of the Engineers' Club of Philadelphia*, October 1908.

¶ *Engineering*, vol. lxxxvii. p. 663.

\*\* Paper read before the American Electrochemical Society, May 6-8, 1909; *Electrochemical and Metallurgical Industry*, vol. vii. p. 270.

†† *Journal of the Franklin Institute*, vol. clxv. pp. 363-370.

‡‡ *Electrochemical and Metallurgical Industry*, vol. vii. pp. 133-136.

A description has appeared \* of a new instrument for use in conjunction with a thermo-couple as a thermo-electric recording pyrometer. The complete equipment comprises a thermo-couple consisting of two nickel alloy rods suitably insulated and protected, the recording electric pyrometer, and the leads or wire for connecting the thermo-couple and the recorder. The recording gauge consists of a milli-voltmeter carrying a small drop of ink on the pointer or needle. As this milli-voltmeter system is in a horizontal position, there is no change in weight or position of the pointer with an increase or decrease of ink.

A new quick-reading form of the Bristol electric pyrometer, specially designed for use when the temperatures are excessively high and the requirements more than usually severe, is described and illustrated.†

E. F. Northrup ‡ describes and illustrates a new type of pyrometer, designed by the Leeds and Northrup Company, Philadelphia. The instrument depends for its working upon the change in the electrical resistance of pure platinum under variations of temperature. In addition to the bulb which contains the platinum, and is inserted in the furnace, the instrument consists of two parts, an indicator and a deflector. The former gives the actual temperature of the furnace, while the latter shows, not the actual temperature of the furnace, but whether or no it is the desired temperature. To this end it contains an index, which may be adjusted to any desired temperature.

**Fuel Value of Coal.**—D. White§ has studied the composition of coal in order to determine more definitely, from a comparison of a large number of ultimate analyses, the relative importance of oxygen as an impurity in various coals. He also illustrates the transition between various grades of coal of similar origin, and ascertains the relative proportions of carbon, hydrogen, and oxygen in coking coals, with special reference to a theory tentatively framed to explain the coking quality. Calorimeter tests show that two coals having the same carbon content, but with the reverse proportions of ash and oxygen (one with 15 per cent. of ash and 4 per cent. of oxygen, the other with 4 per cent. of ash and 15 per cent. of oxygen), have nearly the same heat efficiency; that is, oxygen and ash are of nearly equal negative values.

In dealing with the effect of the various constituents of coal on the efficiency and capacity of boiler furnaces, D. T. Randall|| and P. Barker state that, contrary to general belief, coal highest in moisture gives the best results; that with a low moisture having a low heating value. As an example of the wide variation in the constituents of coals from various fields of one State, it is shown that

\* *Iron Age*, vol. lxxiv, pp. 176-177. † *Ibid.*, p. 625.

‡ *Electrochemical and Metallurgical Industry*, vol. vii, p. 234.

§ *United States Geological Survey, Bulletin No. 382.*

|| Paper read before the American Society for Testing Materials, June 29, 1909; *Iron Age*, vol. lxxiv, p. 16.

the volatile matter in one grade of coal mined in West Virginia was 17 per cent., while that taken from another mine in the same State was 37 per cent. The ash also showed a variation of 6.5 to 8 per cent.

D. T. Randall \* reports on the value of small anthracite for heating and power purposes.

J. von Ehrenwerth † has continued his work of calculating the temperatures attainable with ordinary fuels.

C. M. Ripley ‡ discusses the characteristics of bituminous coals and low grade fuels.

L. P. Zimmerman § gives a detailed result of a comparative test of coal and shavings as boiler fuel.

N. A. Carle || deals with the determination of the heat value of coal from Dulong's formula, based on ultimate analysis.

J. E. Steely ¶ in dealing with the economic combustion of coal, shows how unreliable an indication is the percentage of carbon dioxide in determining chimney losses without considering hydrogen, carbon monoxide, and moisture.

A. C. Scott \*\* deals with the decrease in weight of lignite in transit, and details the results of experiments with Texas lignite, to determine changes in weight and heat value due to temperature and humidity conditions.

A. L. Hodges †† compares the heating values of wood, charcoal, peat, and various kinds of coal, coal gas, and water gas.

M. Kaufhold ‡‡ shows, by the help of diagrams, the quantity of heat wasted in ordinary firing with coal, and enters into a consideration of the efficiency of the economisers used for heating feed water, &c., giving their values expressed in the form of fuel saved. Reference is also made to artificial draught, and to the approximate limits within which savings may be effected by its application.

**Selection of Fuel by Analysis.**—J. B. C. Kershaw, §§ in discussing the choice and control of fuel supplies by steamship companies, advocates the basing of the contract price upon the heat value of the fuel rather than upon its weight. He describes the tests required, and shows how the net value of the fuel may be calculated.

At the instance of the Association of Mining Interests in the district of the Dortmund Mining Bureau, |||| a number of experiments have been carried out with a view to ascertaining the practicability of charging for coal according to its calorific value. The results of evaporative tests showed that variations amounting to 25 per cent. of the fuel value were of quite common occurrence. On three grounds the introduction of a system of charging according to calorific value

\* *United States Geological Survey, Bulletin No. 378.*

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lvii. pp. 435-438, 449-455.

‡ *Power*, vol. xxxi. pp. 401-403.

§ *Ibid.*, pp. 442-444.

|| *Ibid.*, vol. xxx. pp. 838-840.

¶ *Ibid.*, pp. 1015-1017.

\*\* *Ibid.*, pp. 842-843.

†† *Mining World*, vol. xxxi. pp. 653-654.

‡‡ *Stahl und Eisen*, vol. xxix. pp. 1346-1351.

§§ *Engineer*, vol. cviii. p. 131.

|||| *Glückauf*, vol. xlv. pp. 708-710.

is considered impracticable. (1) The uncertainty of the process of estimating the value; (2) its unsuitability; (3) the extraordinarily high cost of making the tests. The conclusion is drawn that the price of coals should be regulated according to the object for which they are required.

J. S. Burrows\* reports on the results of purchasing coal under the United States Government specifications, and summarises the advantages accruing to the Government and to the suppliers, due to buying by analysis.

D. T. Randall† discusses various types of furnaces and the coals suitable for use therein. The loss due to moisture is said to be 1 per cent. for every 10 per cent. of moisture present. The percentage of ash is important in its influence on the flow of air and cleaning of fires. Sulphur is undesirable, as it increases clinkering, and is destructive to grate bars. To buy coal on chemical analysis is thought preferable to judging from results of boiler tests, and a specimen specification form is given.

**Classification of Coals.**—A. L. McCallum‡ reviews recent schemes for the classification of coals, and gives the new basis for classification suggested by Parr.

**Calorific Value of Petroleum.**—R. W. Fenn§ compares the value of crude oil with that of coal, and gives a table showing the calorific value of California fuel oils.

**Calorific Value of Gas.**—P. Lemoult|| has worked out a simple method for the determination of the calorific value of combustible gases, based upon the fact that carbon monoxide and hydrogen possess certain similar properties, namely, that when burnt they contract by the same amount in volume, and the products of their combustion can be absorbed by an alkali. The number of calories produced in their combustion is very nearly equal, being 68 and 69 respectively. It is unnecessary, therefore, in the case of a gaseous mixture containing only carbon monoxide and hydrogen, to determine the proportion of these two gases, and a formula is given by which the calorific value of the mixture can be ascertained without so doing.

**Smoke Prevention.**—D. T. Randall¶ and H. W. Weeks report the results of their investigations upon the smokeless combustion of coal under boilers. They find that smoke prevention is possible, but that any one kind of apparatus is effective only if so set under the boilers that the principles of combustion are respected. Mechanical

\* *United States Geological Society, Bulletin No. 378.*

† *Engineering News*, vol. lxi, p. 395.

‡ *Journal of the Mining Society of Nova Scotia*, vol. xii, pp. 113-116.

§ *Engineering News*, vol. lxi, pp. 516-518.

|| *Comptes Rendus*, vol. cxlix, pp. 454-456.

¶ *United States Geological Survey, Bulletin No. 373.*



stoking gives the best results, owing to the regularity which it is impossible to maintain in firing by hand.

D. T. Randall \* discusses the relation of the character of coals to the prevention of smoke, and gives various tables in connection with the question.

## II.—COAL.

**Formation of Coal.**—A résumé is given of the investigations of A. Strahan † and W. Pollard, with a view to obtaining evidence bearing on the causes of anthracitisation; the results of their work appeared in the form of a memoir on the coals in South Wales, published in 1908 by the Geological Survey of England and Wales.

D. B. Dowling ‡ discusses some possible chemical changes in the formation of coal.

E. Coste § deals with the various theories with regard to the origin of coal.

R. D. Vernon || discusses, with illustrations, the geology of the lower coal-measures of Derbyshire and Nottinghamshire.

W. O. Rogers ¶ discusses the formation of coal, and deals with the coal supplies of the United States as tabulated by the United States Geological Survey.

Kratz \*\* discusses the geology of the lower coal-measures of Rhenish Westphalia.

H. Stremme †† deals with the formation of secondary allochthonous brown-coal, and describes deposits at Lausitz, Meissen, and in the Harz district.

**Search for Coal.**—Particulars are given ‡‡ of geological research in the British coalfields during 1908. In England and Wales work has been continued in Devon and Cornwall, Pembrokeshire, and in the Midland counties of Derbyshire and Nottinghamshire. In Pembrokeshire the work of surveying the coalfield and adjacent areas has been carried westwards to the sea, and but little remains to be done to complete the survey of the South Wales coalfield on the 6-inch scale. In the Midlands the field work has proceeded northwards in the Chesterfield and Ollerton sheets. The original survey of Scotland

\* Paper read before the International Association for the Prevention of Smoke, June 24-26, 1909; *Power*, vol. xxxi. pp. 226-228.

† *Engineering*, vol. lxxvii. pp. 566-567.

‡ Paper read before the Canadian Mining Institute.

§ *Ibid.*, March 1909.

|| *Geological Magazine*, N.S., vol. vi., July 1909; *Colliery Guardian*, vol. xcvi. pp. 418-419, 466-467.

¶ *Power*, vol. xxxi. pp. 41-44.

\*\* *Glückauf*, vol. xlv. pp. 729-738.

†† *Zeitschrift für praktische Geologie*, vol. xvii. pp. 310-314.

‡‡ *Summary of Progress of the Geological Survey of Great Britain for 1908*; *Colliery Guardian*, vol. xcvi. pp. 636-637.

has been continued in the neighbourhood of Glencoe and Ben Nevis, in the Island of Mull, and in the counties of Caithness, Perth, Inverness, and Argyll. The revision of the carboniferous areas in the Midland Valley has also been proceeded with.

D. Ferguson\* discusses the geology of the Clyde valley deep coal-fields of the carboniferous limestone series, concealed by the coal-measures and the millstone grit.

A deep boring was made in 1902 in the basin of the Alais in the hope of finding the coal-beds of Saint-Brès prolonged and the super-imposed geological strata thinning out. The result has been disappointing, as the non-coal-bearing strata, though varying in thickness, shows no diminution on the whole.†

L. Delacuvellerie ‡ relates the progress made with the trial borings for coal in the Bassin du Centre, Belgium, at La Hougaerde, Ansuelle, and Buvrines. That in the first-named district has tapped nine seams of coal, varying in thickness from 57 centimetres to 1·16 metre.

A report§ is published of the geological profile of the boring at Winterslag (Campine district).

Lebens|| gives an illustrated description of a device, used at the Genck-Sutendael collieries, for recording the rate of sinking boreholes. It consists of a vertical cylinder, driven by clockwork so as to make a complete revolution in twelve hours, the paper covering the cylinder moving at a velocity of 1 millimetre per minute. The recording pencil is mounted on a nut travelling on a vertical, threaded shaft, rotated by belt and pinion gearing from the flywheel of the rotary drilling plant.

F. Lynde¶ draws attention to the need for careful and systematic prospecting by means of boreholes, and adduces as an example the completeness with which the anthracite coalfield of Pennsylvania has been explored. Diamond core drills are now generally used in prospecting and developing anthracite seams, an advantage of diamond drilling being that a hole can be made at any angle. All cores extracted are placed in core boxes and duly docketed, with details relating to their origin, for future reference. As drillers are not invariably to be depended upon for the identification of strata passed through, the cores are examined by the engineer in charge, who supplements the driller's report. The field being thus thoroughly proved, mining resolves itself into an operation more nearly akin to industrial manufacture.

**Chemistry of Coal.**—A. D. Little,\*\* in discussing the action of sulphur in gas coal, states that about 60 per cent. of the sulphur in

\* Paper read before the Glasgow University Geological Society, March 24, 1909; *Colliery Guardian*, vol. xcvi. pp. 779-780.

† *Genie Civil*, vol. liv. p. 375. ‡ *Annales des Mines de Belgique*, vol. xiv. pp. 237-242.

§ *Annales des Mines de Belgique*, vol. xiv. pp. 337-362.

|| *Ibid.*, pp. 780-781.

¶ *Engineering and Mining Journal*, vol. lxxxviii. pp. 258-260.

\*\* *Ibid.*, vol. lxxxvii. p. 897.

coal remains behind in the coke. The amount of gas per ton of ordinary Westmoreland coal is about 10,750 cubic feet, so that where this coal contains 1·5 per cent. of sulphur an amount of 0·6 per cent., or 13·44 lbs. of sulphur, leaves the retorts per ton of coal. A portion of this passes into the tar, probably over 2 lbs. per ton of coal, leaving nearly 11 lbs. of sulphur to pass off with the gas. The great mass of the sulphur leaving the retorts with the gas is in the form of hydrogen sulphide, and amounts to between 90 to 95 per cent. of the total. The remainder is gaseous sulphur compounds, of which the most important is carbon bisulphide. The author considers that in the effort to obtain the maximum yield of gas, and economy in the production, abnormal amounts of sulphur compounds are formed.

**Coal in Kent.**—Results of analyses of a sample of coal taken from the 6-foot seam, recently struck by the Kent Coal Concessions in their boring near Dover, have been published.\* They yielded :—

*Proximate Analysis—Dry Basis.*

	Per Cent.
Volatile matters . . . . .	25·49
Fixed carbon . . . . .	68·53
Sulphur . . . . .	1·06
Ash . . . . .	4·92
	<hr/> 100·00

	Per Cent.
Coke per ton of coal . . . . .	73·83

*Ultimate Analysis—Dry Basis.*

	Per Cent.
Carbon . . . . .	83·62
Hydrogen . . . . .	5·30
Oxygen . . . . .	4·54
Nitrogen . . . . .	0·56
Sulphur . . . . .	1·06
Ash . . . . .	4·92
	<hr/> 100·00

The coal possesses a heating power equal to the finest Welsh coals, and is well adapted alike for steam-raising, household use, and the manufacture of lighting and power gas.

It is officially announced that another seam of coal 4 feet 2 inches thick has been struck in one of the borings south of Canterbury. The coal, which is hard and bright, is apparently a steam quality, and has a very strong bind roof.†

**Coal in Warwickshire.**—It is stated ‡ that following the operations at Binley, where an excellent seam of slate coal was struck at a depth of 172 yards, the North Warwickshire Coal Company have

\* *Colliery Guardian*, vol. xcvi. p. 417.

† *Ibid.*, p. 285.

‡ *Iron and Coal Trades Review*, vol. lxxviii. p. 576.

reached thick coal at a depth of 800 yards at their Whitmore Park boring. Another boring is being made by the same company, near Corley, at which coal has not yet been reached. In the report to the Royal Commission it was calculated that in the known coalfield of Warwickshire there were still 375,000,000 tons of coal to be worked, whilst in the extensions of the coalfield, after making ample allowance for barriers and faults, there were over 750,000,000 tons available for working.

**Coal in Austria.**—E. von Posch\* and A. Hofmann report the result of their examination of the brown-coal deposits at Collane (Pago Island). They estimate the deposit to contain nearly 3,000,000 tons of saleable coal, with an equal amount of bituminous coal shale, suitable for calcining lime and cement.

A. Polley† describes a coal deposit round Cerovije, Istria, which he estimates to contain 285,000,000 tons of coal.

Borings carried on above Reichenfels, St. Leonhard (Carinthia), are reported‡ to have proved an extensive bed of coal. A seam of lignite has been discovered, at a depth of 25 feet, in digging a well at Pihl (Bohemia), and a similar seam in a quarry near Komt. An important deposit of coal is also reported to have been recently discovered at Reichenfels.

**Coal in France.**—At the Anzin coal-mines a discovery of an anthracite seam 1·70 metre in thickness has been made in the new Edouard Agache pit.§

New borings have been made in connection with the Saarbrücken coalfield, by the Mining Research Syndicate of the Vosges, at the instance of J. Buffet and V. Sepulchre. The first, in December 1908, at Gironcourt-sur-Vraine, a little west of Mirecourt, revealed the existence of a bed of coal 70 centimetres ( $27\frac{1}{2}$  inches) thick at a depth of 700 metres; this coal contained 32 per cent. of volatile matter and may be classed among the bituminous coals, and will, it is hoped, prove a good coking coal. The second boring in January 1909 showed the existence of a bed composed of two layers of coal 40 centimetres and 20 centimetres thick respectively, separated by a band of schist 40 centimetres thick.||

**Coal in Germany.**—The mode of occurrence of the thin brown-coal seams in the neighbourhood of Müncheberg in Brandenburg, and the means by which they are being profitably worked and developed, are considered by Tornow.¶

Knepper\*\* describes the occurrence of brown-coal on the lower Rhine in the region between Cologne and Brühl. The coal is being open-worked at a mine near Brühl.

\* *Montan Zeitung*, vol. xvi. pp. 272-275.

† *Ibid.*, pp. 352-353.

‡ *Colliery Guardian*, vol. xcvi. p. 1023; vol. xcvi. p. 233.

§ *Ibid.*, vol. xcvi. p. 1024.

|| *Génie Civil*, vol. liv. p. 262.

¶ *Glückauf*, vol. xlv. pp. 586-592.

\*\* *Der Bergbau*, May 13, 1909, pp. 227-230.

A promising seam of coal has been struck at a moderate depth at Dahlen (Saxony); and discoveries of workable deposits of lignite are reported from Borna and Lobstädt, as well as from Friedland (Mecklenburg-Strelitz) and Tenplitz (Brandenburg).\*

An important deposit of lignite is reported † from Petershain, Oberlausitz, Prussian Silesia.

**Coal in Greece.**—L. Rohrer ‡ describes the discovery of a deposit of brown-coal, of good quality, reaching 24 inches in thickness, at Kumi near Chalkis.

**Coal in Holland.**—It is reported § that in the province of Gelderland, near Wilderswyk, the Government engineers have struck a coal-seam at a depth of 623 metres.

**Coal in Iceland.**—It is reported || that at Arnarfjord, Dufansel, Iceland, new coal-beds extending for about 4½ miles have recently been discovered. Operations have been started, and a shaft sunk to the depth of about 115 feet.

**Coal in Russia.**—R. Grimshaw ¶ gives a short account of the principal coalfields of Russia.

**Coal in Australia.**—In New South Wales the chief coal-bearing rocks are the "Permo-Carboniferous," in which the great coal-seams of the State are found. The coal is of good quality, suitable for gas, household, and steaming purposes. In Queensland the coal-bearing strata are of vast extent. The Ipswich beds are estimated to occupy about 12,000 square miles, while the Burrum beds occupy a considerably larger area. Bituminous coal is yielded by the Ipswich seams and anthracite of good quality is obtained from the Dawson River bed. The coal-seams in West Australia belong to the Carboniferous and Post-tertiary ages. Most of the coal contains a large percentage of moisture and belongs to the hydro-bituminous class. In Victoria, deposits of black coal occur in the Jurassic system, the workable seams having a thickness of 2 to 6 feet. Deposits of brown-coal of immense extent occur in several parts of the State, but owing to the extreme friability of the material, it requires to be consumed in specially constructed grates. Attempts to manufacture briquettes from the brown-coal have not met with any measure of success.\*\*

**Coal in Queensland.**—It is reported †† that the Burrum Collieries Company, Ltd., have struck a payable seam of good hard coal at a depth

\* *Colliery Guardian*, vol. xcvi. p. 380.

† *Ibid.*, p. 582.

‡ *Montan Zeitung*, vol. xvi. pp. 372-373.

§ *Colliery Guardian*, vol. xcvi. p. 1118.

|| *Iron and Coal Trades Review*, vol. lxxix. p. 50.

¶ *Mining World*, vol. xxxi. p. 517.

\*\* *Mining Journal*, vol. lxxxvi. p. 233.

†† *Colliery Guardian*, vol. xcvi. p. 30.

of 245 feet in their great shaft at Howard, in the Bundaberg district. The coal is said to be of good quality, but the seam varies in thickness.

**Coal in Victoria.**—Samples of coal taken by P. G. W. Bayly\* from the prospecting shaft now being sunk in the Powlett River field show on careful analysis that this is the best coal yet discovered in Victoria. The analysis gave the following results:—

	Per Cent.
Moisture . . . . .	5.12
Volatile hydrocarbon . . . . .	36.34
Fixed carbon . . . . .	55.34
Ash . . . . .	3.20

The fuel produced 58.54 per cent. of coke, and only 0.45 per cent. of sulphur; its specific gravity is 1.28, and its calorific power 13,267 British thermal units. The coking quality distinctly differentiates the coal from this field from any previously found in the State.

A further discovery has been made† on the Powlett River coal-field, the most easterly bore having proved a 3½ foot seam at a depth of 92 feet. This is situated about a mile north-east of the prospecting shaft, and a mile from the bore which disclosed the 9 foot 11 inch seam some months ago. Another bore put down a mile south-west of the prospecting shaft proved the existence of a seam 5 feet 2 inches thick at a depth of 62 feet.

C. H. Wickes‡ reports that large brown-coal deposits have been discovered at Morwell, about 80 miles east of Melbourne. They have been bored to a depth of 1000 feet, of which 800 feet is brown-coal of the best quality. The coal is said to contain 34 gallons of crude oil per ton; it can be used to make producer gas (10,000 feet per ton) and carbide of calcium. It does not contain more than 17 per cent. of sulphur.

**Coal in British New Guinea.**—It is reported§ that coal deposits of great magnitude have been discovered in Papua, several seams 9 feet thick having been seen out-cropping on the cliffs of the river Purari. At present, however, the deposits are inaccessible for practical purposes.

**Coal in Canada.**—E. Kraynik|| deals with the occurrence and production of coal in Canada, and describes the coalfields of Nova Scotia, British Columbia, Vancouver Island, and the North-West territories.

The known coal-seams on six sections of coal land owned by the Hosmer Mines, Limited, at Hosmer, in the Crow's Nest Park

\* *Colliery Guardian*, vol. xcvi. p. 584.

† *Ibid.*, p. 532.

‡ *Board of Trade Journal*, vol. lxvi. pp. 173-174.

§ *Colliery Guardian*, vol. xcvi. p. 788.

|| *Glückauf*, vol. xlv. pp. 577-585, 915-922, 959-969, 995-1005, 1085-1090.

district, South-Eastern Kootenay, number thirteen, and vary in thickness from 4 to 30 feet. The coal is bituminous, high in hydro-carbon, and consequently an excellent coking as well as steam coal.\*

J. P. Howley† describes the coal areas of Newfoundland. There are three distinct carboniferous areas, one in Codroy Valley, west coast, another in the country lying to the south of Bay St. George, and the third on the upper reaches of the Humber River. The composition of the various coals is given.

It is stated‡ that a seam of coal 5 feet in thickness has been discovered at Goose Brook, in the interior of Newfoundland, near the railway, and that there are indications of immense masses of coal in this neighbourhood.

**Coal in Cape Colony.**—E. J. Cattell§ reports that a coal-seam in the Sutherland and Laingsburg districts has been experimentally worked. The workings are situated a short distance up the south-eastern slope of the Roggeveld Mountains. A seam which was found on analysis to be of a semi-bituminous character, has been exposed along the whole length of the work, varying in thickness from 12 to 33 inches.

A most important coal discovery has been reported|| from Cape Colony, in the neighbourhood of Beaufort West, a little over 20 miles from the railway. According to the analysis made by J. G. Rose, the Cape Government analyst, the coal is superior to anything yet discovered in South Africa, containing as it does only 1·12 per cent. of ash; moisture, 0·60; volatile matter, 21·40; fixed carbon, 76·32, and sulphur, 0·56 per cent. The low percentage of ash and moisture show it to be a true coal and not lignitic in character.

The coal-bearing districts of South Africa and the collieries which have been opened up in these regions are described.¶

**Coal in New Zealand.**—It is stated\*\* that a scheme is on foot for the construction of a deep-sea harbour at Point Elizabeth to facilitate the working of the large coal areas in the neighbourhood. The Westland-Grey coalfield, near Point Elizabeth, has an area of about 38,000 acres, and the coal lying *in situ* is estimated at 150,000,000 tons. The outcrops vary from 2 feet to 20 feet in thickness, and contain coal, both bituminous and carboniferous, of high quality.

**Coal in China.**—B. Giles†† states that in Lan-shan-hsien the natives do a considerable amount of primitive coal-mining every year between October and March, at which later date the water

\* *Engineering and Mining Journal*, vol. lxxxvii. p. 896.

† *Canadian Mining Journal*, vol. xxx. pp. 455-461.

‡ *Colliery Guardian*, vol. xcvi. p. 30.

§ *Board of Trade Journal*, vol. lxvi. p. 174.

|| *Colliery Guardian*, vol. xcvi. p. 532.

¶ *South African Engineering*, vol. xi. pp. 1, 17-18, 37, 57-58, 77, 95-96; vol. xii. pp. 1-3, 19.

\*\* *Iron and Coal Trades Review*, vol. lxxix. p. 125.

†† *Board of Trade Journal*, vol. lxx. p. 496.

floods their shafts, and they are compelled to cease operations for lack of pumping machinery. The industry has now been taken in hand by local capitalists intent upon reorganising and developing it. There are at present thirty shafts, of which only two are being profitably worked.

W. P. Ker \* reports on the coal-mining district of Tientsin.

**Coal in Korea.**—Coal occurs largely in Korea, though generally speaking it is not considered of much economic value. The coal when mined crumbles to dust, but bituminous coal is known to exist which has not yet been worked at all.†

**Coal in the Philippines.**—J. B. Dilworth ‡ describes the coal-fields in the Philippine Islands. Practically all the islands contain coal, but one of the most important coalfields is that of Lantauan, in Cebu. The following analyses show the relative composition of Lantauan, Batan, Australian, and Japanese coal :—

	1.	2.	3.	4.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Water . . . . .	17.20	5.75	2.59	2.26
Volatile matter . . . . .	34.69	41.04	34.38	38.43
Fixed carbon . . . . .	44.60	47.64	53.23	50.23
Ash . . . . .	3.51	5.57	9.80	9.08
Sulphur . . . . .	0.60	0.72	0.60	0.78
British thermal units . . . . .	9,664	11,549	12,512	11,992

(1) Lantauan bituminous coal. (2) Batan bituminous coal. (3) Australian coal; average of twelve samples. (4) Japanese coal; average of twenty-five samples.

W. D Smith § states that the East Batan Coal Company's mine is the first one since the American occupation to furnish coal to the general market and the first successful coal property in the whole history of these islands. The coal-seam varies from 5 feet 6 inches to 6 feet, with 3 inches to 4 inches of clay parting 21 inches from the roof, and dips 13° to the north. The coal breaks easily from the face by working up the dip, and does not require the use of coal-cutting machinery.

A. J. Cox || contributes further information upon the character and fuel value of Philippine coal.

**Coal in Siberia.**—W. Hotz ¶ states that about 100,000 tons of coal are raised annually in the Kusnezsk basin, and about 150,000

\* *Board of Trade Journal*, vol. lxxv. pp. 645-646.

† *Mining Journal*, vol. lxxxv. p. 645.

‡ *Bulletin of the American Institute of Mining Engineers*, 1909, pp. 39-50.

§ *Report on the Mineral Resources of the Philippines; Iron and Coal Trades Review*, vol. lxxix. p. 655.

|| *Philippine Journal of Science*, May 1909.

¶ *Zeitschrift für praktische Geologie*, vol. xvii. p. 265.



tons from the northern extension of that basin, to the south of Tomsk.

R. M. Percy\* describes the coalfield of Siberia. The extent of this, so far as the Akmolinsk district is concerned, has not yet been fully determined, although it is known that coal does occur in the whole area between Karagandy and Akmolinsk, a distance of 180 miles. This area, however, represents only one-tenth of the whole area of the Akmolinsk district, and it therefore becomes apparent how enormous are the possibilities concerning coal-mining in this part of Siberia. The Spassky Company's claim at Karagandy is seven miles long and three miles wide. So far three seams have been met with, although the deepest shaft is only 238 feet deep. The seams are 4 feet, 7 feet 6 inches, 28 feet respectively, but only the latter two have been opened out.

**Coal in Turkestan.**—It is reported that in Turkestan there are considerable coalfields awaiting development, the actual yearly production of coal in that province amounting at the present time to 37,100 tons.†

**Coal in German East Africa.**—Young,‡ in his report on the mineral resources of German East Africa, states that coal occurs some 25 miles west of Mwaja, at the north end of Lake Nyassa, and also near Wiedhafen, on the eastern shore of the same lake, but up to the present it has not been worked.

In a report by C. Gagel§ upon the available mineral resources of German East Africa mention is made of the occurrence of coal near Lake Nyassa. The Carboniferous strata contain three seams of lean coal, with a total thickness of about 39 feet and a 12-inch seam of bituminous coal. The strike has been proved for a distance of nearly ten miles. The coal is somewhat ashy, with a calorific power of about 6500 calories.

**Coal in Chili.**—A. Russell|| has published an account of the coal-fields and collieries of Chili. Coal is found almost along the whole length of Chili, although only in the Coronel district have mining operations been carried on on a large scale. The coal found here is a true coal, and may be described as a second-class steam coal.

**Coal in Colombia.**—According to J. White,¶ the Colombian coal-fields are exceedingly well placed to take advantage of the markets which will be made available by the opening of the Panama Canal.

\* Paper read before the Lancashire Branch of the National Association of Colliery Managers, November 12, 1909.

† *Mining Journal*, vol. lxxxv. p. 579.

‡ *Board of Trade Journal*, vol. lxxv. p. 281.

§ *Glückauf*, vol. xlv. pp. 1029-1033.

|| *Transactions of the Mining Institute of Scotland*, vol. xxxii. pp. 13-66.

¶ *Mining World*, vol. xxx. p. 876.

The country has in its extensive coalfields a very valuable asset, almost untouched, and hitherto very little explored.

**Coal in Mexico.**—S. E. Magill\* reports upon the work of development of the coal deposits near Guadalajara, in Mexico. Owing to the abundance of fuel oil, and the development of water power to furnish electricity, the coal deposits near the city are considered of so little importance that very little development work has been done. The known area already explored with drills is 2000 acres, and the estimated area, according to outcrop and direction of vein, 6000 acres more, making a total of 8000 acres. The coal is a very superior form of lignite. The highest percentage of ash shown by analysis has been 8 per cent., and it has gone as low as  $3\frac{1}{2}$  per cent. In all cases the carbon is over 90 per cent.

**Coal in Peru.**—I. R. Dorca† states that the coal formation in the peninsula of Peracas, Peru, is represented by beds of fine-grained sandstones, clays, and schist. The coal basin is a large one, bounded on the north and east by eruptive rocks. Tertiary deposits of small thickness lie on the coal formation. At Punta Huaca a boring put down intersected a seam about 2 feet thick at a vertical depth of 270 feet; a second seam was cut at 370 feet, the core indicating a thickness of 4 feet.

An official report of E. de B. Lukis‡ has been published describing fully the coalfields of Peru. Analyses of coal from the several deposits are given. The most important of the Peruvian fields is that of Huayday.

**Coal in the United States.**—Surveys have been made of coal-fields in Montana, Wyoming, Utah, Colorado, New Mexico, Oregon, and Virginia, and detailed descriptions of the occurrences and character of the coal are given with maps of the districts.§ A classified list of papers dealing with coal, coke, lignite, and peat, published by the United States Geological Survey, is also given.||

M. R. Campbell¶ and E. W. Parker describe the coalfields of the United States, classifying them into six main provinces. Estimates of the coal reserves in the various known coal areas are given, the total of easily accessible coal being computed at 1,382,780,000,000 tons.

J. A. Holmes\*\* gives a résumé of the fuel investigation carried out by the United States Geological Survey in the year ending June 30, 1909. Over 1500 analyses have been made of coals from 500 mines, these representing the larger deposits in all the important fields of the United States.

\* *Iron and Coal Trades Review*, vol. lxxix. p. 346.

† *Mining Journal*, vol. lxxxvi. p. 370.

‡ *Boletín del Cuerpo de Ingenieros de Minas del Peru*, Nos. 64 and 69.

§ *United States Geological Survey, Bulletin No. 341*, pp. 1-418.

¶ *Ibid.*, pp. 419-436.

|| *Bulletin of the American Institute of Mining Engineers*, 1909, pp. 365-372.

\*\* Paper read before the American Society for Testing Materials, June 29, 1909; *Iron Age*, vol. lxxxiv. p. 96.

R. P. Tarr\* deals with the coal resources of Washington, the geological features of the coal area and their influence on the quality of the coal, and the extent and development of the output.

**Coal in Alaska.**—A. H. Brooks† reports that the estimated resources of the Alaskan coalfields are 15,104,000,000 tons. When the vast region is more fully explored, however, it may be found that the available supplies will approximate to ten times that amount. Since 1888, when records were first kept, till 1907, the total quantity of coal mined in Alaska has only been 37,507 tons.

W. W. Atwood‡ gives an account of the coal resources of Alaska.

**Coal in Colorado and Utah.**—G. B. Richardson§ reports on the Book Cliffs coalfield between Grand River, Colorado, and Sunnyside, Utah. At the east end of the cliffs two workable beds are known, the upper one of which measures 9 feet in places, and the lower one is commonly about 4 feet thick. On account of lack of water in the district and the difficulty of access, very little development of the area has yet taken place, but the amount of available coal is estimated at 8,000,000,000 tons.

**Coal in Illinois.**—J. Udden|| describes the geological conditions of the coalfields near Duquoin, Illinois. The principal sediments consist of shales, sandstone, and limestones, associated with which are coal-beds of variable thickness. The blue band seam is the only one that is mined in the area. The blue band coal is found at depths ranging from 45 to 470 feet, and averages in thickness about 6 feet 2 inches.

R. S. Moss¶ describes the development of the Cartersville coalfield, in Southern Illinois. In the Williamson County the output of coal increased from less than 100,000 tons in 1890 to over 5,000,000 tons in 1907.

**Coal in Indiana.**—G. H. Ashley,\*\* in discussing the coals of Indiana, describes them as equal in quality with any competing coal, and capable both of coking and of generating producer gas of high value. The coal-measures of the State are, approximately, 1300 feet in thickness, but the main coal-bearing divisions are comprised within 500 feet. On a conservative basis there are 50,000,000,000 tons of coal in sight, of which 24,000,000,000 tons consists of what, at this time, is considered a workable coal; and at the present rate of mining this supply will last about 1000 years. If, however, mining

\* *Mines and Minerals*, vol. xxx. pp. 17-19.

† *United States Geological Survey, Bulletin No. 394*, pp. 174-188.

‡ *Ibid.*, No. 379, pp. 116-147.

§ *Ibid.*, No. 371.

|| *Illinois Geological Survey, Urbana; Mining World*, vol. xxx. pp. 487-489.

¶ *Mining World*, vol. xxx. 676-678.

\*\* Annual Report of the State Geologist, Indiana; *Engineering and Mining Journal*, vol. lxxxviii. pp. 164-165.

continues in the future to increase as it has done within the last decade, the supply will be exhausted in about 150 years.

**Coal in Kentucky.**—J. Howard \* describes the Middlesboro coal-field, Kentucky, and the principal colliery workings of the area.

**Coal in Montana.**—C. A. Fisher † reports fully on the geology of the Great Falls coalfield. Owing to its geographical position with respect to other coalfields and the quality of the product itself, this field is destined to become the most important one in north-central Montana. Analyses of a number of samples, made at the fuel-testing plant at St. Louis, are given.

**Coal in North Dakota.**—E. W. Parker ‡ reports on the coal-mining industry of North Dakota. All the mineral fuel mined in that State is brown lignite, which is largely manufactured into briquettes.

**Coal in Virginia.**—D. A. Patterson § describes the coal-mining operations in south-western Virginia. The Keokee Coal and Coke Company possess a property of 8000 acres with seven workable seams, containing approximately 300,000,000 tons of coal, varying in thickness from 48 to 96 inches. The coal dips uniformly on a grade averaging  $2\frac{1}{2}$  per cent. On account of the high altitude (2500 feet) all mines are free from excess water; one triplex electric pump discharging all water through a 2-inch line. Two seams are at present being mined; one known as the McConnell, and one as the Wilson seam; the first-mentioned seam is a superior coal showing the following composition:—

	Per Cent.
Moisture . . . . .	3.86
Volatile matter . . . . .	34.13
Fixed carbon . . . . .	56.39
Ash . . . . .	5.62
Sulphur . . . . .	0.79

**Coal in Wyoming.**—C. W. Washburne || has surveyed and reported on the coalfields of Wyoming.

**Peat.**—V. Zailer ¶ states that if wet peat, containing 85 to 90 per cent. of water, is impregnated with 5 per cent. of mineral oil residue, and pressed and dried as usual, a fuel is obtained containing half its weight of oil. The heating value is increased by 25 to 45 per cent., and the dry peat is less hygroscopic than the untreated dry peat.

\* *Engineering and Mining Journal*, vol. lxxxviii. pp. 314-316.

† *United States Geological Survey, Bulletin No. 356.*

‡ *Advance Report of United States Geological Survey; Mining World*, vol. xxxi. p. 173.

§ *Canadian Mining Journal*, vol. xxx. pp. 390-392.

|| *United States Geological Survey, Bulletin No. 341*, pp. 165-199.

¶ *Petroleum*, vol. iv. p. 739.

The Power Gas Corporation, a British company, has erected in Westphalia a plant for gasifying and recovering ammonia from peat, containing 40 to 60 per cent. moisture. Each ton of dried peat yielded 32 kilogrammes of sulphate of ammonia and 2400 cubic metres of good power gas. Other plants are being installed in Norfolk (England) and Italy.\*

E. F. Gray† reports that the production of peat fuel has begun on Froien Island, Norway. The fuel is of excellent quality, and a large consignment has already been sent to the Norwegian State railways.

E. Nyström‡ reports on the uses and manufacture of peat and lignite in Europe. He describes their origin, occurrence, classification, composition, and calorific value.

An investigation of the peat bogs and peat industry of Canada during the season 1908–1909, by E. Nyström§ and S. A. Anrep, has been made on behalf of the Canadian Department of Mines.

E. V. Moore|| deals with the development and the possibilities of the peat-fuel industry in Canada. Peat bogs are widely distributed in almost every Province of the Dominion. The peat averages about 20 feet in depth, and would probably produce about 5000 tons per acre. Efforts to work these deposits have met with little success, and the author gives suggestions whereby a commercial success may be obtained. He also describes the various processes in use.

R. H. Fernald¶ considers that among other developments of the peat industry of the United States that of the use of peat in by-product recovery gas plants promises well. From these plants both gas for power and sulphate of ammonia can be obtained in commercially paying quantities. It has been demonstrated at the experimental plant of the United States Geological Survey that gas for power can be made easily from both Florida and Massachusetts peat.

H. Philipp\*\* discusses the possibilities of the use of peat as a producer of power by both direct firing and gasification.

C. A. Davis†† reports that large areas in Alaska are covered with peat, and considers the possibility of utilising it as fuel in that region.

A. E. Taylor‡‡ describes the various peat deposits of the State of Indiana, and gives their area and geological features.

E. S. Bastin§§ and C. A. Davis direct attention to the economic importance of the more accessible peat deposits of Maine, in the United States. A full report upon the peat bogs in that State is given.

\* *Chemical Trade Journal*, vol. xlv. pp. 34–81.

† *Board of Trade Journal*, vol. lxvi. p. 36.

‡ *Canada, Department of Mines*, Ottawa, 1906.

§ *Ibid.*

|| *Transactions of the Canadian Society of Civil Engineers*, vol. xxii. pp. 82–119.

¶ *Iron Trade Review*, vol. xlv. p. 1172.

\*\* Paper read before the American Peat Society, February 13, 1909; *Electrochemical and Metallurgical Industry*, vol. vii. pp. 117–119.

†† *United States Geological Survey, Bulletin No. 379*, pp. 63–66.

‡‡ *Journal of the American Peat Society*, April 1909.

§§ *United States Geological Survey, Bulletin No. 376*.

S. L. Jodidi\* gives a description of the peat deposits of Michigan, and chemical analyses of various samples, together with notes on their calorific value.

### III.—CHARCOAL.

**Manufacture of Charcoal.**—Z. P. Yuon† gives an account of experiments on the distillation of wood in the Central Urals. The duration of the process from the time of charging to the time of discharging is nine to twelve days. The yield of charcoal always depends on the speed of distillation, and the mechanical properties of quickly fired charcoal are greatly inferior to those of normally carbonised wood.

D. A. Lyon‡ describes the charcoal plant at the works of the Noble Steel Company, California. Charcoal is used as the reducing agent in the electrical furnace plant. The retorts are cylindrical in shape, and are mounted in an upright position in concrete and brick, there being four retorts to a battery. The wood is placed in cages similar in shape to the retorts themselves, and these cages are then placed in the retorts. After the distillation of the wood is complete the cage containing the charred wood is taken from the retort and placed in a cooling stand until its temperature has been lowered below the glowing point of the charcoal. When the charcoal has cooled it is discharged into the charcoal storage bin, which is cylindrical, and entirely closed except for an opening near the top just large enough to receive the bottom of the cage through which the charcoal is discharged. The wood is reduced to charcoal containing about 95 per cent. carbon. The portion of the vapour capable of condensation is collected in tubular condensers, and the residual gases are led under the furnace and burned. The following are specimen analyses of charcoal from the company's ordinary beehive ovens:—

	I.	II.	III.
	Per Cent.	Per Cent.	Per Cent.
Water and volatile matter . . . . .	5.3	7.8	6.5
Ash . . . . .	0.5	0.7	0.6
Carbon . . . . .	94.2	91.5	92.9

An illustrated description is given§ of a plant recently erected at Donald, Ontario, for the destructive distillation of wood. The process in use for the production of charcoal is described.

\* *Journal of the American Peat Society*, April 1909.

† *Chemical Trade Journal*, vol. xlv. pp. 87-88.

‡ Paper read before the American Electrochemical Society, May 1909; *Electrochemical and Metallurgical Industry*, vol. vii. pp. 252-253.

§ *Canadian Machinery*, May 1909, pp. 33-36.

E. Haanel\* describes in detail the modern methods of manufacturing charcoal.

#### IV.—COKE.

**Coking Coal.**—J. F. Bell† gives results of experiments with gas coals, which were partly undertaken to ascertain the effect of varying the weight and period of carbonisation upon the production of the residual products. Any appreciable improvement in the quality of the coke produced by modification of the carbonising process is worthy of investigation. The author's experiments with charges of six, eight, ten, and twelve hours' duration—the weight of charge being varied in direct proportion to the time of carbonisation—prove conclusively that by using heavy charges, by which the period of distillation is prolonged, a higher grade of coke is produced, the colour is more lustrous, and the coke is more dense and less friable.

A. L. McCallum‡ discusses the influence of organic sulphur on coal during the coking process.

**Tests of Coke.**—D. Bagley§ describes some characteristic features of English coking coals and new recovery processes. The history of the by-product coke-oven is briefly sketched. From a series of tests the conclusions arrived at are that generally in the blast-furnace the unit consumption of coke, made from identical coals in the beehive and retort ovens, favours the beehive variety slightly. The economic advantages derived from the use of the retort oven, however, far outweigh any inferiority in its product, and as its design and construction progress, even the question of quality may ultimately favour the by-product oven.

A. W. Belden|| has carried out an extensive series of coking tests for the United States Government on fourteen samples of raw coal, washed coal, and mixtures of raw and washed coal, with a view to ascertaining what improvement can be effected in the quality of coke by washing the coal.

**Modern Coke-oven Plant.**—The under-flue coke-ovens installed at the Stag Cañon Fuel Company's works, Dawson, New Mexico, are described and illustrated. The washed slack is hauled from storage tanks to the coke-ovens by two Scott-Dale electric lorries, each

\* *Canada, Department of Mines*, Ottawa, 1909; Report on the investigation of an electric shaft furnace, Domnarfvet, Sweden.

† Paper read before the Institution of Gas Engineers, June 1909; *Iron and Coal Trades Review*, vol. lxxviii. p. 965.

‡ *Canadian Mining Journal*, vol. xxx. pp. 531-532.

§ Paper read before the Mining and Metallurgical Section of the Seventh International Congress of Applied Chemistry, June 1, 1909.

|| *United States Geological Survey, Bulletin* No. 368.

pulling one trailer. There are 570 ovens in operation, 124 being beehive ovens 13 feet in diameter, and the remaining 446 being English under-flue ovens 11 feet in diameter. These ovens are in batteries of 54 to 58 each, arranged in a double row. The flaming gases from the coke-oven, passing downward into horizontal flues beneath the oven, serve to coke the slack at the bottom while it is being coked at the top.\*

C. L. Cantley † gives an illustrated description of various modern retort coke-ovens, with special reference to the practice of the Nova Scotia Steel and Coal Company.

**Beehive Coke-ovens.**—F. W. Parsons ‡ states that at the Coalton plant of the Davis Colliery Company, Coalton, West Virginia, there are 200 beehive coke-ovens, arranged in two blocks of 100 each, the floors of which fall to the front on a slope of 7 inches in 12 feet. The net tonnage of each oven is about 3·8, while the coke yield averages 73 per cent.

**Pyrometry of the Beehive Coke-oven.**—J. R. Campbell § describes the pyrometry of the beehive coke-oven and the devices used and methods employed in taking temperatures, with special reference to practice in the Connellsville region. Details are given of a number of experiments and examinations of beehive coke-oven gases evolved during the coking process, and the following general conclusions are drawn. The maximum temperature attained in a small type of beehive oven, with low volatile matter, is 2200° to 2400° Fahr.; with a large type of beehive oven and comparatively high volatile matter, 2400° to 2600°, and with a large type of beehive oven, comparatively high volatile matter, and a flue system for operating boiler plant, 2700° to 2900°. From the foregoing it may be deduced that (a) a low grade refractory material will serve its purpose in a furnace of the first type, hence the longevity of this type of furnace; (b) that such material is unsuitable for use in No. 2, and causes many troubles, such as falling roofs, and (c) that only the highest grade of refractory material will stand the heat of ovens of No. 3 type.

**By-product Coke-ovens.**—W. H. Blauvelt || deals with certain types of by-product coke-ovens, their methods of working, and the various mechanical, chemical, engineering, and metallurgical problems presented by the operation of the by-product oven.

An illustrated description is given ¶ of the by-product coke-oven

\* *Bulletin of the American Institute of Mining Engineers*, 1909, pp. 554-557.

† *Transactions of the Canadian Society of Civil Engineers*, vol. xxii. pp. 398-433.

‡ *Engineering and Mining Journal*, vol. lxxxvii. p. 1287.

§ Paper read before the Coal Mining Institute of America, June 29, 1909; *Engineering and Mining Journal*, vol. lxxxviii. pp. 120-123.

|| *Transactions of the American Society of Mechanical Engineers*, vol. xxx. pp. 385-422.

¶ *Iron and Coal Trades Review*, vol. lxxix. pp. 390-391.



plant, erected at the Emley Moor and Park Mill Colliery. The installation comprises thirty-two horizontal-flue ovens of the non-regenerative type. One of the main features of these ovens is that there is a solid partition wall between each oven, supporting the weight of the arch and ironwork, and also forming a reservoir of heat, which is claimed to reduce greatly the time occupied in coking.

An illustrated description of the Huessener waste heat coke-oven and by-product plant, with detailed drawings showing the construction, has appeared.\*

Details, with illustrations, are given† of the Koppers improved coke-oven and by-product plants erected at Flimby and Siddick, near Maryport and Workington, in Cumberland. The coal carbonised yields 68 per cent. of large coke,  $5\frac{1}{2}$  per cent. of tar, and  $1\frac{1}{2}$  per cent. of sulphate of ammonia. The surplus gas amounts to over 50 per cent. of the total quantity evolved from the coal, and at present is conducted to existing boilers at the collieries. The distinguishing feature of this improved system is the extraction of ammonia direct from the gas in the form of sulphate of ammonia without the employment of a water-scrubbing process.

R. Gunderson‡ gives a general description of a plant of 280 Koppers by-product coke-ovens now in use at the works of the Illinois Steel Company, Joliet.

A. V. Kochs§ deals with the Koppers coke-oven and by-product plant.

C. G. Atwater|| describes the progress in by-product coke-oven construction at the works of the Citizens' Gas Company, Indianapolis. The plant will consist of fifty United-Otto ovens and accessory apparatus, together with the auxiliary water-gas plant, gas-holders, purifiers, and compressor station. Details are given of the coke-ovens, the dimensions of which are as follows: 34 feet long, 7 feet 6 inches high, and 17 inches in mean width, while the coal capacity is about 7.5 tons net.

An illustrated description¶ is given of the new coke-ovens and by-product plant recently erected at the Auckland Park Colliery, Bishop Auckland. The plant consists of 100 ovens of the Semet-Solvay type, having a total coking capacity of 5000 tons per week, or 50 tons per oven, with a by-product plant for the recovery of tar and ammonia, and for the conversion of the last named into sulphate.

An illustrated description\*\* of the Semet-Solvay coke-oven and by-product recovery plant erected at the Beighton Colliery of the Sheffield Coal Company, Limited. The charge weighs over 7 tons, and the coking operation takes from twenty-six to twenty-eight

\* *Colliery Guardian*, vol. xcvi. pp. 114-117.

† *Ibid.*, pp. 14-17.

‡ *Progressive Age*, May 1, 1909.

§ Paper read before the Seventh International Congress of Applied Chemistry, June 1, 1909.

|| *Iron and Coal Trades Review*, vol. lxxviii. p. 611.

¶ *Ibid.*, pp. 895-896.

\*\* *Colliery Guardian*, vol. xcvi. pp. 970-971.

hours ; the output per oven per week is about 30 tons of coke of first-class quality.

E. Lloyd \* deals with the Simon-Carves coke-oven.

**Coke-oven Gases.**—E. Cuvelette † deals with the direct utilisation of coke-oven gases in internal combustion motors, and after describing the different types of coke-ovens, emphasises the necessity for purifying the gases, concluding with a dissertation on the mechanical and economic advantages of coke-oven gases for the direct generation of power, and a description of the plant and motors in use at the Lens collieries.

M. H. Mills ‡ makes a comparison between the value of surplus gas from the regenerator by-product coke-ovens, and that of steam produced by the waste heat from by-product coke-ovens, with special reference to the new Coppée by-product ovens.

At many coking plants in Germany where gas-engines have not yet been installed, the coke-oven gases are utilised for raising steam in boilers. The Terbeck method of application, and the apparatus for burning the gases, are described and illustrated.§

A plant for converting the ammonia in coke-oven gas into nitric acid by an electric current has been installed at the Lothringen colliery,|| the resulting dilute nitric acid being saturated with gaseous ammonia, thus furnishing ammonium nitrate for the manufacture of explosives.

Hase ¶ discusses the progress made towards the utilisation of coke-oven gas for illuminating purposes, especially in America, and describes the conditions existing at Essen and Mülheim, Germany, where such use is made of oven-gas.

**Coking Accessories.**—An illustrated description has appeared \*\* of a combined charging and pushing machine, with mechanical leveller, in operation at the Koppers coke-ovens of the Weardale Steel, Coal, and Coke Company, at Spennymore.

An illustrated description is given †† of the Covington coke drawing and loading machine which is installed at the plant of the Atikokan Iron Company, Port Arthur, Ontario.

W. Maurice ‡‡ describes an electrically operated coke drawing machine used in Pittsburg. The device consists of two principal parts—an extractor for withdrawing the coke from the ovens and a conveyor for screening and loading it into trucks.

\* Paper read before the Seventh International Congress of Applied Chemistry, June 1, 1909.

† *Bulletin de la Société des Ingénieurs Civils de France*, vol. lxii. pp. 171-222.

‡ Paper read before the Institution of Mining Engineers; *Colliery Guardian*, vol. xcvi. p. 1231.

§ *Glückauf*, vol. xlv. pp. 592-594.

|| *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. lvii. pp. 81-82.

¶ *Journal für Gasbeleuchtung*, vol. lii. p. 101.

\*\* *Iron and Coal Trades Review*, vol. lxxix. p. 205.

†† *Canadian Mining Journal*, vol. xxx. pp. 399-401.

‡‡ Paper read before the National Association of Colliery Managers, March 27, 1909; *Iron and Coal Trades Review*, vol. lxxviii. p. 533.

## V.—LIQUID FUEL.

**Origin of Petroleum.**—L. Mrazec \* discusses the geological occurrences of petroleum and other hydrocarbons and their organic origin.

H. Höfer † maintains the view that petroleum was originally formed from the remains of marine fauna, and that it occurs in primary formations only.

E. Coste ‡ discusses the origin of petroleum, refuting the theory that it has been formed from organic deposits.

M. Rakusin § deals with the paraffin content of petroleum as a criterion for judging its relative geological age.

**Oil Shale in Scotland.**—R. Weed || describes the oil-shale works and mines at Broxburn, which cover an area of 250 acres. There are at present being worked in these mines three seams of oil-shale, known as the Broxburn, the Burly, and the Grey seams, which are 6 feet, 16 inches, and 6 feet respectively in thickness.

**Petroleum in India.**—Sir T. H. Holland ¶ describes the development of the Burmese oil industry. The wells are still dug by hand to a depth of 400 feet. The fields yield 138,000,000 gallons of crude oil a year. A steel pipe 10 inches in diameter and 297 miles long conveys the oil to the refineries at Rangoon, replacing the barge transit on the Irawadi. There is an oil-field of the same age in Beluchistan and Persia; but it is unimportant owing to the geological conditions being unfavourable to the collection of the oil.

G. de P. Cotter \*\* has surveyed the southern part of the Gwergy Hills and the continuation of their structure to the south. Several wells have been drilled, but the oil occurs in too small a quantity to be profitable.

**Petroleum in Saghalien.**—M. Rakusin †† states that petroleum has been found in the northern narrowest portion of the island of Saghalien; in the eastern portion near where the river Ocha flows into the Okhotsk Sea, and in the southern portion about 200 miles south of the Gulf of Tschai, and 265 miles from Port Alexandrowsky, the chief town of the island. The northern deposit comprises the so-called great asphaltum lake, together with other similar but smaller deposits. Test borings in this district showed that below the layer of asphaltum

\* *Petroleum Review*, vol. xx. pp. 278, 303-304.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lviii. pp. 331-336.

‡ Paper read before the Canadian Mining Institute, March 1909.

§ *Berichte*, vol. xlii. pp. 1211-1215.

|| Lecture delivered before the Cambrian Mining School; *Iron and Coal Trades Review*, vol. lxxix. pp. 205-206.

¶ "Sketch of the Mineral Resources of India," Calcutta, 1908.

\*\* *Records of the Geological Survey of India*, vol. xxxvii. pp. 225-234.

†† *Petroleum*, vol. iv. pp. 510-511, 806-810.

(9 to 21 inches deep) were strata of greenish-grey clay alternating with greenish or brownish-red bituminous sand, and from the borings up to 16 to 32 kilogrammes of crude petroleum were obtained daily. The southern deposit, consisting of what are known as the kerosene lakes, is of a somewhat similar character, the petroleum being below a layer of asphaltum.

**Petroleum in the Philippines.**—W. D. Smith \* notes the frequent association of petroleum with the occurrence of coal in the Philippine Islands. The most promising deposits seem to be on the east coast of Tayabas province.

**Petroleum in Egypt.**—The discovery of oil at Gebel Genesah, about 150 miles south of Suez on the Red Sea coast, has aroused considerable interest, although it is too soon to form any opinion as to the value of the discovery.†

**Petroleum in the Argentine Republic.**—Schultz ‡ states that though petroleum occurs in many places in Argentina the resources have hitherto remained undeveloped on account of the great difficulty of transport. The exploitation of the oil-fields would be of considerable industrial importance in view of the fact that the country possesses no other fuel resources.

**Petroleum in Canada.**—C. Baskerville § discusses the economic possibilities of the American oil shales, and considers that the shale-oil industry could profitably be revived in America, and particularly in New Brunswick. A short sketch of the shale-oil industry is given, dating back to the grant of the first patent for extracting "oyle" from a "kind of stone" from Shropshire, made in 1694 to Ele, Hancock & Portlock, and reviewing the subsequent progress of the industry in England, Scotland, and France. A. Gesner claims to have been the first to produce illuminating oil from bituminous materials in America, and, as far back as 1846, to have burned, in lamps, oil obtained by distilling coal in Prince Edward Island. Nine years later the North American Kerosene Gaslight Company, who had acquired Gesner's patents, manufactured the oil at their works at Newton Creek, and placed it on the market as kerosene oil. This industry prospered, and in 1860 there were fifty-five coal-oil companies in existence in the United States, a list of them being given. Many of the plants were, however, of small capacity, and the discovery of petroleum paralysed the industry. The owners, threatened with considerable loss, solved the difficulty by converting their works into refineries.

\* *Mineral Resources of the Philippine Islands; Engineering and Mining Journal*, vol. lxxviii. p. 170.

† *Mining Journal*, vol. lxxxv. p. 548.

‡ *Petroleum*, April 21, 1909, pp. 805-806.

§ *Engineering and Mining Journal*, vol. lxxxviii. pp. 149-154, 195-199.

A list of the chief minerals exploited and the yield of crude oil per ton is given. One of the most important is the bituminous shale of New Brunswick or the "Albert" shale, which first came into prominence through the discovery, at the Albert Mines, of the peculiar mineral, albertite. The composition of albertite is as follows, the first column being taken from an analysis by Wetherill and the second from one by Gesner:—

*Analyses of Albertite.*

	Per Cent.	Per Cent.
Carbon . . . . .	86.307	85.400
Hydrogen . . . . .	8.962	9.200
Nitrogen . . . . .	2.930	3.060
Sulphur . . . . .	trace	trace
Oxygen . . . . .	1.971	2.220
Ash . . . . .	0.100	0.120

Albertite yielded 90 to 110 gallons of crude oil per ton; and, owing to its freedom from sulphur, the oil, 70 per cent. of which was lamp oil, burned almost without offensive odour. Other oil-bearing shales are described, together with the methods employed in the industry for retorting the coal and shale and refining the crude oil, and the geology of the New Brunswick shales and the principal areas, Taylorville, Albert mines, and Baltimore. Laboratory examinations of shale from Baltimore revealed its possession of the following properties: lustre, moderate; fracture, irregular and without lines of cleavage; cross fracture, angular and partly inclined to conchoidal. The average composition was as follows: moisture, 0.35 per cent.; volatile matter, 44.77 per cent.; fixed carbon, 5.95 per cent.; ash (phosphoric acid, 0.3 per cent., trace of chromium), 48.93 per cent. Total sulphur, 1.43 per cent.; sulphur in coke, 0.20; nitrogen, 1.96. Experimental distillation by the Tervet method having shown the shales to be worthy of more extensive examination they were then tested on a commercial scale. The yield in oil, in these circumstances, was approximately 40 imperial gallons per ton, together with 77 lbs. of ammonium sulphate. A table is also given showing the yield of Scottish and other shales. Of the New Brunswick samples one yielded no less than 54 gallons of oil and 110 lbs. of ammonium sulphate.

It is reported \* that the shale deposits of New Brunswick are far richer than those of Scotland. The Scotch shale produces 30 to 40 gallons per ton, and the New Brunswick shale would, according to Ells, produce from 60 to 110 gallons per ton.

The petroleum industry of Newfoundland is reviewed.†

**Petroleum in Colombia.**—J. White ‡ states that known deposits of oil exist in many parts of Colombia, and indications are found

\* *Chamber of Commerce Journal*, August 1909.

† *Canadian Mining Journal*, vol. xxx. p. 558.

‡ *Mining World*, vol. xxxi. p. 650.

from the Magdalena River to the Atrato River along the Atlantic seaboard. For some distance up one of these rivers oil is often found floating on the surface.

**Petroleum in Mexico.**—J. D. Villarello\* describes the chief petroleum-bearing regions of Mexico, and their geological features. He considers the petroleum in these regions to be a product of the decomposition of matter derived from marine fauna.

H. W. Wilson† reports that a great impetus has been given to the oil industry in the Tampico district, Mexico, by the boring of the Dos Bocas well. The oil produced is strictly a fuel oil.

D. T. Day‡ gives a brief review of the oil-fields of Mexico, their geology, and the character of the oils.

**Petroleum in the United States.**—D. T. Day,§ reporting on the conservation of the petroleum resources of the United States, estimates the quantity of petroleum available as 15,000 million barrels. If the present rate of increase in production be continued, this supply will be exhausted about the year 1935.

R. B. Woodworth|| gives an historical review of the petroleum industry of the United States, and describes in brief the various fields.

P. E. Barbour¶ describes the oil resources and industry of Los Angeles, California, which are in many ways unique. The oil belt extends through one of the best residential portions of the city, and private residences are confronted or surrounded with pumping wells, or derricks stand in close proximity to palm trees adjoining lawns. The existence of oil-bearing formations was known to the early settlers, and in several places where oil sands outcrop the oil oozing out has had its more volatile constituents evaporated, thus leaving a residuum mixed with more or less earthy impurities, and known as "brea." This brea was formerly used as fuel, and for waterproofing the roofs of adobe houses. The Los Angeles fields are in the oil belt extending for more than 100 miles, from Santa Barbara on the north-west to Puente on the south-east. The formation is of Middle Eocene age, and has the form of a flat anticlinal, although somewhat broken. Oil was first found within the city limits in 1892, but development did not become rapid until two years later, when a well put down in a residential section yielded a good quantity of oil. The resulting boom led to no less than 1500 wells being drilled within the next five years. In 1908 the production amounted to 5,138,853 barrels of 42 gallons each.

\* *Mining Journal*, vol. lxxxv. p. 609.

† *Ibid.*

‡ *Petroleum Review*, vol. xx. p. 323.

§ *United States Geological Survey, Bulletin No. 394*, pp. 30-50.

|| *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xxv. pp. 245-312.

¶ *Engineering and Mining Journal*, vol. lxxxviii. pp. 365-366.

**Methods of Working Petroleum Wells.**—F. A. Talbott\* describes a new method of extracting oil from boreholes that has been successfully used in the oil-fields of Galicia. The system comprises an endless band or cable, covered on one side with an absorbent material which is of sufficient length to become immersed at its lowest extremity in the liquid in the borehole. As the band passes through the liquid a certain proportion of the fluid becomes absorbed by the material covering the cable, which, upon arrival at the surface, is passed between two rollers, which press out the liquid.

R. B. Woodworth† discusses the development and design of steel oil derricks as used in the oil areas of the United States, and gives illustrations and dimensions of the standard types adopted in Pennsylvania, California, and elsewhere.

R. Weed‡ describes the method of working the oil-shale mines at Broxburn, Scotland.

**Uses of Petroleum.**—A. B. Thompson§ discusses modern practice in the employment of liquid fuel. The actual calorific value of the different constituents of crude petroleum varies little, so that if properly burned petroleum residues will yield nearly as high an efficiency as the lighter products. Ordinary residuum and heavy crude oils have an approximate composition of 83 to 85 per cent. of carbon and 11 to 13 per cent. of hydrogen, and they usually contain small percentages of oxygen, sulphur, and nitrogen. The British Admiralty specification limits the percentage of sulphur to 0·75 per cent., but in civil practice it is not usual to limit the sulphur, and the author has observed no ill effects in boilers where oils containing as much as 1·5 per cent. sulphur were in constant use. In prolonged tests crude oils have been found to have a more corrosive effect than residuum oils. The calorific values of the residuum of various oils are given.

An article has appeared|| on the use of heavy petroleum oils for locomotives, either alone or together with wood, or with inferior coal. In Roumania their use has so largely superseded that of imported coal that the amount of the latter has dropped in ten years from 98,900 tons to 11,600. Two distributors invented by M. Dragu and by C. Cosmovici are described with diagrams, and the methods of storage and transport are shown in detail.

Kermode's liquid fuel systems are illustrated and described.¶ Oil fuel which has a calorific value of 19320 British thermal units per lb. is, theoretically, capable of evaporating 20 lbs. of water from and at 212° Fahr., and if the air-jet system be used, 15·6 to 16·6 lbs. of

\* *Engineering and Mining Journal*, vol. lxxxvii. pp. 1001-1003.

† *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xxv. pp. 245-312.

‡ Lecture delivered before the Cambrian Mining School; *Iron and Coal Trades Review*, vol. lxxix. pp. 205-206.

§ *University of Birmingham Engineering and Mining Journal*, July 1909, pp. 74-80.

|| *Genie Civil*, vol. liv. pp. 238-240.

¶ *Steamship*, vol. xx. pp. 465-470.

water can be evaporated per lb. of oil consumed under practical conditions. With the pressure-jet system 14 to 15 lbs. of water, and with the steam-jet system 13.6 to 14.8 lbs. of water would be evaporated per lb. of liquid fuel.

J. S. S. Brame\* has lectured at the Sir John Cass Technical Institute on liquid fuel and its economic aspects.

**Transport of Petroleum.**—It is stated† that pipe-line connections have been completed by which it is possible to pipe oil from the Oklahoma wells to New York harbour, a distance of 1500 miles. This is the longest pipe-line in existence in the United States, and indeed in the world.

E. M. Ivens‡ describes some tests carried out upon compressed-air pumping plants erected for the transport of oil from the Louisiana oil-fields.

**Asphalt.**—R. Anderson§ states that asphaltite occurs in Eureka county, Nevada, as a filling in fractures within steeply-dipping Carboniferous strata. The principal deposit follows a zone of fracturing in the sandstone and shale beds, and this vein has been traced about 100 yards. It is probable that the asphaltite of this region is widely extended.

C. Richardson|| deals with the composition of Trinidad asphalt, and describes the method of analysis. With regard to its physical structure, observations and experiments show that the water is held by the clayey matter, the definite ratio of water and clay being due to the capacity of the mineral matter for water; and that the deposit has been formed by the bitumen coming into contact with the original clay-mud of the Trinidad Lake.

T. H. Boorman¶ compares the average composition of crude and refined asphalts from Trinidad, Bermudez, and Nigeria, and shows the ultimate composition of pure bitumen from these asphalts.

## VI.—NATURAL GAS.

**Natural Gas in Russia.**—At Surachany and Amiradschan, in the Baku oil-field, there are occurrences of natural gas. The gas has been used for a long time as fuel for burning lime, and more recently on a larger scale in the petroleum distilling plants. Such a large supply of gas was opened up in the Surachany plain in 1903 that it became possible to use it as fuel in the adjacent Balachany oil-field as well as in the district of its origin. The use of natural gas as fuel

\* *Petroleum Review*, vol. xxi. p. 237.

† *Engineering and Mining Journal*, vol. lxxxvii. p. 1198.

‡ *Journal of the American Society of Mechanical Engineers*, vol. xxxi. pp. 341-359.

§ *United States Geological Survey, Bulletin No. 380*, pp. 283-285.

|| *Proceedings of the American Society for Testing Materials*, vol. vi. pp. 509-518.

¶ *Engineering and Mining Journal*, vol. lxxxvii. p. 1037.



at Baku is of considerable importance, for in this oil-field 15 per cent. of the total production of crude oil is used in producing power for boring and transporting purposes; moreover, the yield of crude oil is steadily falling.\*

F. Schmidt † reports an outburst of natural gas in an arterial boring on the island of Koksär, 25 miles north-east of Reval.

**Natural Gas in Canada.**—Under the supervision of E. Coste, a well has just been completed to the depth of over 1900 feet, and has proved to be a gusher of 7,000,000 cubic feet of natural gas per day. It is situated near the banks of the South Saskatchewan River. Illustrations are given ‡ of the well burning before it was tubed and closed in.

**Natural Gas in the United States.**—D. T. Day§ reports on the natural gas resources of the United States. The duration of high pressure in the known fields probably never exceeds 100 lbs. per well after ten years. The pumping of the gas promises a continued supply. The outlook is, that natural gas will be available for as long a period as has already elapsed since the industry began.

J. G. Barry|| describes a preliminary investigation of the natural gas field in Bottineau county and eastern Ward county, North Dakota. Four wells have shown good flows of gas, from each of which, it is reported, there is a flow of 2,000,000 cubic feet of gas per day at a pressure exceeding 100 lbs. per square inch. An analysis shows the following results: Hydrogen, 0·5 per cent.; methane, 82·7 per cent.; ethylene and other illuminants, 0·2 per cent.; carbon monoxide, 1·2 per cent.; oxygen, 3·0 per cent.; nitrogen, 12·4 per cent. The British thermal units were calculated at 886 per cubic foot.

**Pumping Natural Gas.**—S. B. Redfield¶ gives an illustrated description of the gas-engine driven compressing units, which are installed at the plant of the Mohican Gas and Oil Company, Howard, Ohio, for the purpose of pumping the natural gas from the wells situated within a radius of 35 miles from the pumping station to distant towns and cities where it is to be used. These wells are from 2600 to 2800 feet deep, and the gas is brought to the pumping station in pipes varying from 6 to 10 inches in diameter.

\* *Journal für Gasbeleuchtung*, vol. lii. p. 435.

† *Verhandlungen Mineralogische Gesellschaft*, St. Petersburg, vol. xli. pp. 43–45.

‡ *Canadian Mining Journal*, vol. xxx. pp. 200–201.

§ *United States Geological Survey, Bulletin* No. 394, pp. 51–61.

|| *Engineering and Mining Journal*, vol. lxxxvii. pp. 1089–1090.

¶ *American Machinist*, vol. xxxii., Part I., pp. 880–884.

## VII.—ARTIFICIAL GAS.

**Gas-producers.**—A. B. Searle \* deals with gas-producers in connection with the smelting of various metals and the utilisation of poor fuel.

An illustrated description of the S. F. H. gas-producer is given by Sepulchre.† Cleansing of the gas is carried out by fusing the cinders and dust produced.

Brüll ‡ describes the Letombe gas-producer for lean coal or coke.

Improvements in producers specially designed to work with wet fuel are described by J. Gwosdz.§

An illustrated description is given || of the Goehtz mechanical gas-producer.

An account of the Thompson suction gas-producer, illustrated by diagrams showing its construction, has appeared.¶ It is made in sizes varying according to requirements, and is designed for continuous working.

J. E. Dowson \*\* discusses the comparative advantages of suction and pressure plants in the use of producer gas, with illustrations of the most recent modifications.

Some notes on the manufacture and working of suction gas-producers are published.††

H. O'Connor ‡‡ deals with suction gas plants.

T. W. Burt §§ deals with the development of the suction gas-producer.

Fielding and Platt's bituminous gas-producer is illustrated and described.|||| Analyses of gases obtained in the producer from coal and from wood are given.

A suction gas-producer capable of using bituminous coal is illustrated and described.¶¶

The construction and method of working of a producer for gasifying bituminous coal is described.\*\*\* It is of the suction type, with two combustion zones, one at the top and one at the bottom of the producer. Analyses of several kinds of fuel which have been tried are given.

\* Paper read before the Seventh International Congress of Applied Chemistry, June 1, 1909.

† *Revue de Métallurgie, Mémoires*, vol. vi. pp. 730-733.

‡ *Bulletin de la Société d'Encouragement*, vol. cxi. pp. 473-479.

§ *Braunkohle*, April 6, 1909, pp. 25-27.

|| *Iron and Coal Trades Review*, vol. lxxviii. p. 930.

¶ *Iron Age*, vol. lxxxiv. pp. 478-479.

\*\* *Nature*, vol. lxxx. pp. 200-203, 232-233.

†† *Engineer*, vol. cviii. pp. 79-80, 129-130, 155-156.

‡‡ Paper read before the Western District of the Scottish Junior Gas Association; *Iron and Coal Trades Review*, vol. lxxviii. p. 861.

§§ *Cassier's Magazine*, vol. xxxvi. pp. 125-135.

|||| *Engineer*, vol. cviii. pp. 317-318.

¶¶ *Engineering*, vol. lxxxvii. p. 786.

\*\*\* *Engineering Record*, vol. lix. pp. 817-819.

An illustrated description is given\* of the Morton suction gas-producer for bituminous coal.

J. Gwosdz † describes recent practice in the construction of gas-producers for bituminous fuels. Sectional drawings are given of the Gáloscy and Terény producers, of the Sauer producer, of the Dresden Gas-producer Company's producer, of the Deutz Gas-engine Works plant, and those of Versen, Ising, Körting, and of Crossley Brothers.

J. B. Klumpp, ‡ C. A. Graves, and I. E. Moulthrop state that a series of experiments on various types of gas-producers have been made, having for their object the development of a satisfactory producer suited to the use of various forms of bituminous fuels. The design involved a producer capable of (1) continuous operation, (2) producing a gas free from tar, (3) operating at such temperatures as would avoid troublesome clinker formation, and (4) producing a gas of normal constituents suited to high engine compression. The results led to the present form of Westinghouse double-zone gas-producer. A description and illustrations of the plant are given, together with the results of a full year's continuous testing with various fuels and under varying conditions.

In dealing with the recent developments in producer-gas plants, C. B. Lamont § and N. Latta describe a new type of suction gas-producer designed for operation on bituminous and lignite coals, principally the soft coals of the Pacific coast and other western states of America.

C. W. Obert || gives an illustrated description of a small producer gas power plant, and of its work in connection with the driving of both refrigerating and electric-generating machinery. The gas is generated by two Smith updraught suction producers, each equipment consisting of a simple shell generator, a wet scrubber, and a dry purifier.

The gas-producer plant of the Aber colliery, Ogmore Vale, is described ¶ and illustrated.

The power gas plant installed at the Nostell colliery, near Wakefield, is described \*\* and illustrated.

**Peat-gas Producers.**—J. J. Astor †† has devised a new method of producing gas from peat. The apparatus consists of a vibratory disintegrator which utilises the expansive force of the air and gases within the peat to disrupt and disintegrate the peat and thus permit

\* *Colliery Guardian*, vol. xcvi. pp. 213-214.

† *Glückauf*, vol. xlv. pp. 738-743.

‡ Report of the Committee on Gas-engines, read before the National Electric Light Association, June 1909; *Engineering News*, vol. lxii. pp. 13-15.

§ Paper read before the Pacific North-West Society of Engineers, May 8, 1909; *Iron Trade Review*, vol. xlv. pp. 987-988.

|| *Journal of the American Society of Mechanical Engineers*, vol. xxxi. pp. 653-662.

¶ *Iron and Coal Trades Review*, vol. lxxviii. pp. 780-781.

\*\* *Ibid.*, vol. lxxix. p. 245.

†† *Scientific American*; *Times Engineering Supplement* July 7, 1909, p. 18.

it to be thoroughly and uniformly heated. The gas generated may be supplied to an ordinary internal combustion engine.

Since the erection of the first peat-gas plant at Skabersjö in 1903 several more have been erected in Sweden totalling over 2000 horse-power.\*

O. K. Zwingenberger† discusses the advantages and disadvantages of peat as fuel, and gives a description of a gas-producer for peat.

C. A. Davis,‡ in dealing with the gasification of peat, describes some of the methods employed, and shows how, from one of the lowest grades of fuel, it is possible to obtain gas for power and heating, as well as a high-grade coke and sufficient by-products to pay for the entire cost of the operation.

E. Nyström§ gives an illustrated description of various peat-gas producer plants.

**Producer Gas for Power Purposes.**—T. E. Butterfield|| describes experiments carried out with a view to securing higher efficiency in gas-engines by diluting the mixture of gas and air with an inert gas, whereby it is possible to decrease the speed of combustion and permit higher compression. An analysis is also given, expressed in equations, showing the effect of, and explaining, such dilution, together with tables comparing the thermal data for an undiluted charge and one diluted with inert gas.

G. D. Stephen¶ deals with suction gas and its application to mining, and describes a plant installed at the Threlkeld Mines, Cumberland. The results are also given of a test carried out to determine the coal consumption under varying working loads in winding and pumping.

C. E. Lucke,\*\* in dealing with the value of gas power, states that a comparison of gas with steam power plants will show that the principal differences are in coal and water consumption per horse-power hour, in first costs, and life. The gas power plant is more efficient thermally than the steam plant, and generally more costly. The coal cost will be lower for the gas plant and higher for the steam plant, but this saving is offset by an increased fixed charge due to higher first cost, and, in some cases, shorter life, and to charges due to greater space occupied.

W. D. Ennis†† deals with the chemical reactions and the thermal results in a typical suction producer, and shows that its efficiency may be raised by reducing the sensible heat of the gas delivered.

J. K. Clement,‡‡ L. H. Adams, and C. N. Haskins give data on the rate of formation of carbon monoxide in gas-producers.

\* *Engineering*, vol. lxxxvii. p. 661.

† *Journal of the American Peat Society*, April 1909.

‡ *Cassier's Magazine*, vol. xxxvi. pp. 343-353.

§ *Canada, Department of Mines*, Ottawa, 1908.

|| *Journal of the American Society of Mechanical Engineers*, vol. xxxi. pp. 489-499.

¶ *Engineering and Mining Journal*, vol. lxxxvii. pp. 1076-1077.

\*\* Proceedings of the Pan-American Scientific Congress, Santiago, Chili, December 1908; *School of Mines Quarterly*, vol. xxx. pp. 199-216.

†† Paper read before the American Institute of Chemical Engineers, June 24, 1909.

‡‡ *University of Illinois, Bulletin No. 30*, February 1, 1909.

J. Voigt\* considers the influence of steam and of the loss by radiation upon the gasifying of solid fuel in the gas-producer.

H. I. Lee,† in discussing new methods adopted in the manufacture of gas, considers the possibility of providing the heat required for carburetting producer gas by burning a portion of the gas while in process of generation and allowing the products of such combustion to remain in the finished product.

N. T. Harrington‡ deals with the loss of fuel weight in a freshly charged producer, and gives the results of a test made in connection with the subject. The apparatus used was a suction gas-producer and gas-engine, of which illustrations are given.

F. E. Junge§ describes, with illustrations, recent developments in the utilisation of low-grade fuels in gas-producers.

B. G. Maclellan|| deals with the problems involved in the production of power gas from low-grade fuels.

O. Nagel,¶ in dealing with the combustion of producer gas, gives illustrated descriptions of mixing devices for gas and air.

It is expected\*\* that the lignite-coal resources of Texas will be made more valuable than at present by the adoption of a process recently perfected at the Pittsburg Experimental Station of the United States Geological Survey. The average grade of lignite contains about 35 per cent. of moisture. In the experiments in the manufacture of producer gas from lignite a number of by-products and much ammonia were obtained.

**Water Gas.**—According to P. Breteau †† several methods are in use for lowering the carbon-monoxide content of water gas. Franck directs a current of the dry gas upon a mass of carbonate of lime heated to 300°. The Jouve-Gautier process depends upon the relative viscosity of the several gaseous constituents, which property affects the speed at which they pass through unglazed porcelain plates. The method of the Lyons Gas Company depends upon the power of superheated steam to convert carbon monoxide into carbon dioxide and hydrogen.

W. Heym ‡‡ discusses the advantages of water gas as compared with carbonic oxide for the purpose of power production.

**Gas Cleaning.**—A description has appeared §§ of the gas-cleaning plant of the Barrow Hæmatite Steel Company.

\* *Ton-industrie Zeitung*, vol. xxxii. pp. 1735-1737, 1798-1801, 1853-1857.

† Paper read before the Illinois Gas Association, March 17, 1909; *Mining World* vol. xxx. pp. 841-842.

‡ *Transactions of the American Society of Mechanical Engineers*, vol. xxx. pp. 511-515.

§ *Power*, vol. xxxi. pp. 184-185.

|| Paper read before the Seventh International Congress of Applied Chemistry, June 1, 1909.

¶ *Electrochemical and Metallurgical Industry*, vol. vii. pp. 202-203.

\*\* *Power*, vol. xxxi. p. 269.

†† *Journal de la pharmacie et chimie*, vol. xxviii. pp. 500-503.

‡‡ *Gasmotorentechnik*, vol. viii. pp. 176-179.

§§ *Iron and Coal Trades Review*, vol. lxxviii. pp. 775-776.

W. D. Mount\* describes, with illustrations, a simple method of cleaning gas conduits.

**Gas-Engines.**—P. R. Allen† deals with recent developments in large gas-engine design under the following headings, viz.: (a) The four-cycle engine—British and Continental practice; (b) the four-cycle engine—American practice; (c) and two-cycle engines. Many illustrations are given.

L. S. Marks‡ discusses the horse-power, friction losses, and efficiencies of gas and oil engines.

W. H. Watkinson§ discusses the use and economies of large internal-combustion engines for land and marine purposes.

W. F. Flint|| discusses the possibilities of gas-engines and their operation with bituminous coal gas-producers, with special reference to central station work.

The new blast-furnace gas-engine plant of the Barrow Hæmatite Steel Company is described ¶ and illustrated.

An illustrated description is given \*\* of two twin-cylinder two-cycle double-acting gas-engines recently installed at the Aber colliery, Ogmores Vale.

J. B. van Brussel†† gives an illustrated description of the gas-engine plant at the Anna II. mine of the Eschweiler Mining Company, at Alsdorf, Germany. The gas-engines are driven by coke-oven gas whereby the power requirements of the colliery are covered at a minimum cost. The plant comprises two engines each of 500 brake-horse-power, two of 1000 brake-horse-power each, one of 1200 brake-horse-power, two twin-tandem engines each of 2400 to 2600 brake-horse-power, and two engines of 2600 to 2800 brake-horse-power. Results of tests on the two 2400 brake-horse-power engines are also given.

## VIII.—COAL-MINING.

**Shaft-sinking.**—S. F. Walker,†† in dealing with shaft-sinking by the freezing process, describes its use in England, Germany, and France. The difficulties met with in the employment of this process and the methods of dealing with them are also described.

\* *Transactions of the American Society of Mechanical Engineers*, vol. xxx. pp. 437–442.

† *Cassier's Magazine*, vol. xxxvi. pp. 195–210, 308–327, 445–469.

‡ *Transactions of the American Society of Mechanical Engineers*, vol. xxx. pp. 423–435.

§ Paper read before the Liverpool Engineering Society; *Steamship*, vol. xx. pp. 452–456.

|| Paper read before the Canadian Electric Association, June 1909; *Iron Age*, vol. lxxxiv. pp. 256–258.

¶ *Iron and Coal Trades Review*, vol. lxxviii. pp. 775–776.

\*\* *Ibid.*, pp. 780–781.

†† *Engineering and Mining Journal*, vol. lxxxvii. pp. 1189–1190.

‡‡ *Mines and Minerals*, vol. xxx. pp. 41–44.

F. Donaldson \* describes modern methods of shaft-sinking.

J. S. Martin † gives particulars relative to the sinking operations in the Southern coalfields.

E. M. Bainbridge ‡ and W. M. Redfearn describe the method employed at the Newbiggin colliery for sinking through sand.

The use of steel-sheet piling for shaft-sinking is dealt with, § and an illustrated description is given of its use in the sinking of a shaft at the Newbiggin colliery, Northumberland.

R. Steven || describes the operations connected with the sinking and fitting of two circular shafts, and gives some notes and observations made during the sinking. The shafts were of the same dimensions—namely, outside diameter, 15 feet; finished size, 13 feet; and depth, 480 feet. Details of the costs per fathom are given.

An illustrated description has appeared ¶ of a shaft-sinking plant recently supplied to the Hamsterley Colliery Company. There is a centrifugal pump delivering 500 gallons per minute against a 90-foot head. The motor, of the three-phase squirrel-cage type, develops 30 brake-horse-power, and is supplied with alternating current at 550 volts, 50 cycles.

Dehasse \*\* describes the method adopted for repairing the cast-iron tubbing at the Harchies pit, by a lining of steel rings strengthened by T-iron, cement being injected behind the outer tubbing, to consolidate the surrounding earth.

S. Stassart †† describes the means adopted for repairing a caved-in ventilating shaft at the Buisson colliery. The shaft was filled with ashes (faggots having proved ineffectual) to a point above the seat of the caving, and piles were driven through the solid mass and lined with tubbing. Owing to the influx of firedamp, special means had to be adopted for connecting the upper part of the shaft with the workings, so as to maintain the ventilating current.

G. Lemaire ‡‡ gives particulars of the sinking of a staple shaft, for ventilating purposes, at the Quesnoy pit, Bois-du-Luc colliery, the upper part of the shaft being driven in an upward direction, and the lower part downwards from the same level.

In sinking a shaft at the Oberkirchen colliery, §§ through wet sand and gravel, a bricked sinking-curb, greased on the outside with soft soap, was employed, but could not be got down farther than 14½ metres, so that, for the further sinking, a column of tubbings had to be used, cement being injected behind the tubbings.

\* *Mines and Minerals*, vol. xxix. pp. 459–463, 515–518, 563–566.

† Annual Report on the Inspection of Mines and Quarries in the Southern District, No. 12; *Iron and Coal Trades Review*, vol. lxxix. p. 91.

‡ Paper read before the Institution of Mining Engineers, September 15, 1909.

§ *Iron and Coal Trades Review*, vol. lxxix. p. 456.

|| *Transactions of the Mining Institute of Scotland*, vol. xxxii. pp. 6–12.

¶ *Colliery Guardian*, vol. xcvi. p. 1166.

\*\* *Annales des Mines de Belgique*, vol. xiv. pp. 756–759.

†† *Ibid.*, pp. 725–735.

‡‡ *Ibid.*, pp. 761–766.

§§ *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. lviii. pp. 34–35.

To test the staunchness of the caulking in the joints of the tubbing, and at the same time shut off the pressure of water from the rear, in sinking the shaft at the Hildesia colliery,\* thin cement was forced in behind the tubbings, under a pressure of 80 to 90 atmospheres.

H. E. Coll† describes the sinking and timbering of the Allan shafts, Stellarton, Pictou county, Nova Scotia.

**Use of Concrete in Mines.**—R. H. Rowland ‡ gives an account of the sinking of a shaft lined with concrete. The shaft was put down by an Oklahoma mining company as an air and escape shaft, 330 feet in depth, at one of their mines. The shaft was circular in shape, 9 feet 6 inches in diameter, and lined with concrete, the thickness of which, owing to the nature of the excavation, varied from a minimum of 6 inches to a maximum of 10 inches. The work proceeded without difficulty, and the average cost, over all, was \$27·56 per foot.

Kaufmann§ describes the operation of lining a new shaft at one of the collieries of the Gelsenkirchen Mining Company with reinforced concrete. The shaft was sunk to a depth of 835 metres, the concrete lining being 30 to 34 centimetres thick.

**Subsidence.**—J. Piggford|| furnishes some notes on subsidences caused by coal-working at Teversal and Pleasley collieries, and concludes that the amount of surface subsidence caused by the removal of coal-seams is largely dependent upon several factors, amongst the most important of which are: (1) the thickness of the seam; (2) the thickness of hard intervening strata; (3) the proximity of faults; (4) the depth at which the coal lies from the surface; and what is perhaps one of the most general causes, (5) the frequent occurrence of fissures, or open cracks, in the surface rocks, which are generally filled in part with sand or other soft material, and form natural reservoirs for rain and other surface water.

**Explosives and Blasting.**—An Explosives in Coal Mines Order has been issued¶ from the Home Office, under date April 2, 1909, amending the Order of December 17, 1906. Particulars are given of the following explosives, viz., amasite, dominite, and St. Helen's powder, and a complete list of the names of permitted explosives as defined in the schedule to the Explosives in Coal Mines Orders of December 17, 1906, of April 8, 1907, of May 26, 1908, and of April 2, 1909, is specified. The Secretary of State for the Home Department gives notice that by an Order dated April 20, he has removed the explosives "Saxonite" and "Geloxite" from the list of permitted explosives for use in mines to which the Explosives in Coal Mines Order of December 17, 1906, applies.

\* *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. lvii. pp. 38-39.

† *Journal of the Mining Society of Nova Scotia*, vol. xii. pp. 11-22.

‡ *Engineering and Mining Journal*, vol. lxxxviii. pp. 359-361.

§ *Glückauf*, vol. xlv. pp. 622-628.

|| *Transactions of the Institution of Mining Engineers*, vol. xxxviii. pp. 128-131.

¶ *Colliery Guardian*, vol. xcvi. p. 843.



Experiments carried out in the Prussian State collieries at Knurów with carbonite, nobilite, fulmenite, and astralite, in order to find a substitute for black powder for blasting rock in wet workings, resulted in favour of astralite, as yielding the smallest quantity of fumes, and also being suitable for use in getting down coal without loss of round coal.\*

Hatzfeld † points out that in 1884 a station for the testing of safety explosives was established by the Prussian Government near Neunkirchen, which has since developed into a testing establishment for general mining purposes. A description of the arrangements is given.

C. Hall ‡ gives detailed descriptions, with illustrations, of the gas and dust gallery and apparatus used by the Explosives Section of the Mine Accident Division of the United States Geological Survey in testing explosives for use in coal-mines.

T. Monte § and W. Will deal with testing of the safety of explosives in firedamp and coal-dust.

Testing the safety of explosives is dealt with by K. Beyling.||

O. Poppenberg ¶ deals with the decomposition, heat of combustion, and explosion temperature of explosives.

P. Chalon \*\* describes exhaustively the manufacture and application of detonating fuses for shot-firing in mines. The invention was introduced thirty years ago by Seebert for the firing of military mines, but has received attention for industrial purposes only recently. It consists of a flexible tin tube charged with melinite, and capable of being readily bent into any form, and easily inserted in position.

Shot-firing by electricity is dealt with, and an illustrated description of the "Sterling" exploder is given.††

Shot-firing in mines is dealt with by L. Barthelemy.‡‡

F. Heise §§ considers the practicability of introducing into the Westphalian mines the system of simultaneous shot-firing by electricity on a plan similar to that in use for several years at the Sunnyside mine in Utah, as recently described by D. Harrington.||||

A description ¶¶ is given of the appliances used in the Recklinghausen and Shamrock pits for preventing the spread of dust in drilling shot-holes, the dust being collected in a receptacle surrounding the drill, and in the one case drawn away by a jet of compressed air. At the Knurów colliery the rock-drillers are provided with aluminium respirators.

\* *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. lvii. p. 26.

† *Glückauf*, vol. xlv. pp. 797-804.

‡ Paper read before the Seventh International Congress of Applied Chemistry, London.

§ *Ibid.*

|| *Ibid.*

¶ *Ibid.*

\*\* *Revue Universelle des Mines*, vol. xxv. pp. 258-273; vol. xxvi. pp. 1-12.

†† *Iron and Coal Trades Review*, vol. lxxviii. pp. 778-779.

‡‡ Paper read before the Seventh International Congress of Applied Chemistry, London.

§§ *Glückauf*, vol. xlv. pp. 653-656.

|| *Engineering and Mining Journal*, vol. lxxvii. pp. 243-246.

¶¶ *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. lvii. p. 25.

**Electricity in Collieries.**—G. R. Wood \* deals with the use of electricity in coal-mining, and gives brief suggestions as to the proper voltage, the insulation of underground electric wires, automatic trolley switches, and return circuits.

W. E. Dickinson † reviews the progress in the application of electricity to mining. After a careful study of the conditions in coal-mines, he concludes that the three-phase system is the safest and most economical method of distributing power in such mines.

C. S. McGinnis ‡ considers the application of the direct-current motor in mining service.

T. J. McKavanagh § deals with the application of electricity to mining.

W. Maurice || describes various electric motors and switch gears for use in mines.

C. L. C. Fichtel ¶ describes methods for electrical wiring in deep mining work, and notes the special requirements and precautions to be observed.

W. H. Patchell \*\* describes the electric equipment of the Ferndale collieries, South Wales.

The electric plant of the Clifton colliery, Nottingham, is described. ††

J. Paul ‡‡ describes the extensive electrical installation at the collieries of the Lochgelly Iron and Steel Company, Limited, Fife.

The electric equipment of the Xhorré pit, Kessales-Artistes colliery, is described by Viatour. §§

The electric installations at the Ressaix and Courcelles collieries respectively are described by Defalque ||| and Delrée; ¶¶ and the regulations for the use of electricity in Belgian mines are published. \*\*\*

The electric plant recently installed at Shamrock colliery, belonging to the Bergwerksgesellschaft Hibernia, Herne, is described and illustrated. ††† It comprises one low-pressure and two live-steam turbines, together producing about 4300 kilowatts, and has been constructed by Brown, Boveri & Co.

R. Nelson ††† deals with the practical application of electricity to mining from the point of view of safety.

\* Paper read before the Coal Mining Institute of America, June 29, 1909; *Engineering and Mining Journal*, vol. lxxxviii. pp. 19-21.

† *Sibley Journal of Engineering; Mining World*, vol. xxx. pp. 629-630.

‡ *Mining World*, vol. xxx. pp. 579-580.

§ Paper read before the Mining Society of Nova Scotia; *Canadian Mining Journal*, vol. xxx. p. 206.

|| Paper read before the National Association of Colliery Managers, March 27, 1909; *Iron and Coal Trades Review*, vol. lxxviii. pp. 532-534, 575-576.

¶ *Engineering and Mining Journal*, vol. lxxxviii. pp. 516-517.

\*\* *Proceedings of the South Wales Institute of Engineers*, vol. xxvi. pp. 848-916.

†† *Iron and Coal Trades Review*, vol. lxxix. p. 624.

‡‡ *Transactions of the Mining Institute of Scotland*, vol. xxxi. pp. 253-272.

§§ *Annales des Mines de Belgique*, vol. xiv. pp. 770-774.

||| *Ibid.*, pp. 242-246.

¶¶ *Ibid.*, pp. 247-259.

\*\*\* *Ibid.*, pp. 373-466.

††† *Engineer*, vol. cvii. p. 508.

††† Paper read before the Institution of Mining Engineers, May 27, 1909.

S. A. Simons\* discusses the precautions to be observed for protection against risk of accident arising from the use of electric plant in coal-mines.

Causes of the occurrence of accidents in collieries due to electricity and the means of the prevention of these are discussed.† In some cases it is stated mine-owners are replacing the electrical drive by dry compressed air. The Miners' Federation is said to be unfavourably disposed towards electrical working, but so far it has deferred taking action in view of the fact that the appointment of a select committee to consider the matter has been promised by the Government. No case can, however, be made out at the present time against electricity as a distributing agent for power in mines. The deaths resulting from accidents in the coal-mines of Great Britain average about 1200 a year, of which not more than 13 have been due, during 1909, to the use of electrical apparatus.

**Power Plant for Collieries.**—A. Burnett‡ considers that the application of gas power to mining presents no great difficulty. For air-compression the substitution of a gas-engine for a steam-engine is little more than a question of design, and gas-driven electric generators for distribution of power to scattered units are quite feasible.

C. B. Chartres§ discusses the utilisation of exhaust steam in collieries.

**Compressed Air in Collieries.**—A detailed description is given|| of a large steam-driven, two-stage, three-cylinder air-compressor. The machine is designed for an output of 5000 cubic feet of free air per minute when supplied with steam at a pressure of 140 lbs. per square inch. The three air cylinders are all of the same dimensions, being in the larger part 37 inches in diameter and in the smaller 29½ inches. The flywheel is 8 feet 6 inches in diameter, and weighs 13,450 lbs.

A description is given¶ of an air-compressor, which is one of two that are to be installed at the Marianna Mines of the Pittsburgh-Buffalo Company, Pennsylvania. The compressor is of the cross-compound, two-stage type, having a capacity of 3600 cubic feet of free air per minute, delivered at 100 lbs. pressure, when running at 75 revolutions per minute.

An illustrated description has appeared\*\* of various types of the "Belliss" air-compressors.

J. Havlicek†† considers the efficiency and performance of work of

\* *Journal of the Institution of Electrical Engineers*, vol. xliii. pp. 197-215.

† *Engineering*, vol. lxxxviii. p. 518.

‡ Paper read before the Canadian Mining Institute; *Mining World*, vol. xxx. pp. 775-777.

§ *Proceedings of the South Wales Institute of Engineers*, vol. xxvi. pp. 750-774, 835-847.

|| *Iron Trade Review*, vol. xlv. pp. 31-35.

¶ *Iron Age*, vol. lxxxiv. p. 175.

\*\* *Iron and Coal Trades Review*, vol. lxxix. pp. 49-50.

†† *Zeitschrift des Vereines deutscher Ingenieure*, vol. liii. pp. 561-568.

various types of electrically driven air-compressors for supplying power to mines.

C. Sangster \* states that the capacity for storage of compressed air in mines is usually very small. In an American mine the idea has been successfully carried out of sealing up an unused cross-cut so as to form a large underground air-receiver. The capacity of this reservoir is 22,000 cubic feet, and it will hold 176,000 cubic feet of free air when compressed to eight atmospheres. The advantage due to avoidance of fluctuations in the load on the machines is very noticeable.

**Coal-cutting Machinery.**—Particulars are given † of a recent very satisfactory piece of work performed by the "Pick-quick" bar coal-cutter in a thin seam of high inclination at a colliery in the east of Scotland. The seam in question is 2 feet in thickness, with a sandstone roof, there being no dirt at top or bottom, and it lies at an inclination of 27°. The cut was made at a height of 16 inches in the seam, the coal being overcut. The length of face was 130 yards, the distance between gateways being 21 yards. The lineal face of 130 yards, or an area of 141 yards, was cut in a shift of ten hours.

An illustrated description is given ‡ of the Steavenson electrically driven coal-cutter, with particulars as to its working in a colliery near Barnsley.

A. Gradenwitz § gives an illustrated description of a process of coal-cutting which is based on the use of cables carrying tempered steel cutting-points, the cables being driven by one or two machines. The cutting machine consists mainly of a double-groove winch with automatic tightening gear. The cable travels at the rate of 5 feet 8 inches per second, or about 340 feet per minute. The advantages and cost of cutting by this process are dealt with.

In a modified form of Korfmann percussion machine tried at the Heinitz colliery, || a rotary motion (quarter or half turn as desired) is imparted to the piston, and thence to the bit, at each stroke. The cutting edges of the bit are sloped to facilitate penetration into the coal, and a higher efficiency is obtained, in firm coal, than with the older type of machine.

An electric percussive coal-cutter of a new type comprises within the same frame the electric motor and the air cylinder. The motor drives through gearing the primary or air-compressing piston working in the forward part of a cylinder. In the same cylinder is a second piston connected with the striking pick, but having no mechanical connection with the first. By means of the air which is compressed by the first piston, the second piston is alternately driven backwards

\* *Power*, vol. xxxi. pp. 193-194.

† *Colliery Guardian*, vol. xcvi. p. 985.

‡ *Ibid.*, vol. xcvi. p. 421.

§ *Engineering and Mining Journal*, vol. lxxxvii. pp. 1236-1238.

|| *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. lvii. pp. 28-29.

and forwards, but is always prevented by cushioning from striking at either end of the stroke.\*

G. Strahl † discusses the various types of coal-cutting machines.

S. F. Walker ‡ compares the merits of various coal-cutting machines, deals with the question of costs, and shows the economy of machine mining. He also discusses the question of compressed air as compared with electric power.

K. Drews § reviews the present position with regard to the use of electric coal-cutting machinery.

W. E. Garforth || recounts his experience, extending over twenty years, in working seams by coal-cutting machinery.

J. Gibson ¶ deals with the subject of machine-mining under difficulties in the Arigna district in the county of Roscommon. Having specified the practical difficulties encountered, the various devices and alterations which were tried in order to minimise them are enumerated, and the results of the machine cutting are noted as follows: (1) the coal hitherto left in has been got at a less price than hand-cut ordinary coal, although, of course, the value of the coal is less; (2) no extra cost is entailed in working; and (3) there is no extra cost for narrow places through broken ground. The cost of working an ordinary seam is lowered, and the usual advantages of machine working are realised.

G. R. Wood \*\* gives the results of investigations into the production of dust by different undercutting machines. At the mines of the Washington Coal and Coke Company, on the lower edge of the Connellsville region, the following quantities of dust were produced per square foot of coal undercut:—

	Lbs.
Hand-mining . . . . .	1·80
Puncher machine . . . . .	4·58
Chain machine with pick-pointed bits . . . . .	1·48

At the mines of the Westmoreland Coal Company the puncher machine gave 6·18 lbs., and the chain machine, with standard chisel bits, gave 2·43 lbs. of dust per square foot. At the Midland No. 1 mine of the Pittsburg Coal Company the chain machine gave 2·43 lbs. and 2·51 lbs. at two different trials, and the puncher machine gave 6·18 lbs.

**Preservation of Mine Timber.**—J. M. Nelson †† discusses methods for the preservation of mine timber. All timber should

\* *Mining World*, vol. xxx. p. 748.

† *Montan Zeitung*, vol. xvi. pp. 394–395.

‡ *Engineering and Mining Journal*, vol. lxxxvii. pp. 1042–1046.

§ *Dinglers polytechnisches Journal*, vol. cccxiv. pp. 225–228.

|| *University of Birmingham Engineering and Mining Journal*, July 1909, pp. 58–68.

¶ *Transactions of the Mining Institute of Scotland*, vol. xxxi. pp. 235–244.

\*\* Paper read before the Coal Mining Institute of America, June 29, 1909; *Engineering News*, vol. lxii. p. 71.

†† Paper read before the Coal Mining Institute of America, June 29, 1909; *Engineering and Mining Journal*, vol. lxxxviii. pp. 211–212.

be peeled, and the injection of creosote, or its application by careful painting, is strongly advocated.

**Mine Supports.**—Comparative trials at the König colliery (Saar) demonstrated the superiority of Douglas fir over pine, both in toughness (length of fibre), bearing power, and buckling strength. Pointed props have been found useful at the Camphauser colliery, where several varieties of telescopic iron props have also behaved well, especially for supporting face conveyors. A telescopic prop, used at the Neu-Essen pit, consists of two half-tubes joined together by bolted flange rings. The tube is partly filled with discs of peat, topped by small fragments of rock, a wooden prop projecting from the top. To dismount the prop, a slit in the tube is uncovered by removing a flange ring, and the filling is raked out, thus allowing the wooden prop to descend into the tube.\*

W. R. Crane † discusses the advantages of concrete for use in the support of underground workings. The first cost exceeds that of timber, but the period of service is much longer.

J. A. Elliott ‡ describes and illustrates a method of utilising reinforced concrete for making mine props. The props are constructed in suitable moulds, and stiffened with angle bars or other sections of iron.

The cost of replacing timbering by concrete lining in a cross-cut at the Ewald colliery is given.§ By putting in concrete lining at once it is found possible, at the Grund colliery, to recover all the timber, for use over again, before it has been damaged by roof pressure.

Niess || describes the precautions to be adopted for supporting mine workings in districts where the pressure of superincumbent strata is excessive.

**Methods of Working.**—J. Kane ¶ discusses colliery working without blasting, and describes the mode of working at the Watts-town and Risca collieries, where, with an output of 1,000,000 tons per annum, no shot has been fired for over five years at Risca, nor for three years at Wattstown.

A. W. Grazebrook \*\* describes briefly the methods of working the thick coal-seams in South Staffordshire.

A. Hall †† gives a résumé of present-day mining operations, especially those common to the South Staffordshire and Warwickshire coalfields.

\* *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. lvii. pp. 41–43.

† *Transactions of the Institution of Mining Engineers*, vol. xxxvii. p. 560.

‡ *Mining World*, vol. xxxi. p. 592.

§ *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. lvii. p. 39.

|| *Glückauf*, vol. xiv. pp. 761–773, 953–959, 989–995.

¶ Paper read before the South Wales and Monmouthshire branch of the National Association of Colliery Managers, September 25, 1909; *Iron and Coal Trades Review*, vol. lxxix. pp. 589–590.

\*\* *University of Birmingham Engineering and Mining Journal*, July 1909, pp. 81–82.

†† Presidential Address before the South Staffordshire, Warwickshire, and Worcester-shire branch of the National Association of Colliery Managers, June 12, 1909; *Iron and Coal Trades Review*, vol. lxxviii. pp. 1014–1016.

A. Baijot\* and A. Demeure contribute notes on the mining practice in the coalfields of Rhenish-Westphalia, the Nord, and the Pas de Calais, with special reference to the use of the water-flush system of hydraulic packing as employed at collieries in these regions.

At the Oskar shaft, Petershofen, the boiler ashes are used for goaf packing, after being soaked in water for twelve hours to insure thorough extinction. The bends in the water-flush packing pipes at the Consolidation colliery, Gelsenkirchen, are strengthened with concrete and wire netting, which increases the working life of the pipes threefold. The down-pipe used in water-flush packing at the Deutscher-Kaiser colliery is lined with loose earthenware pipes, the intermediate space being filled with thin cement. This treatment prevents the breaking of the inner pipes whilst in use. At the Neue Hoffnung brown-coal pit the goaf is packed by boring holes through the roof so as to let through the overlying quicksand, barriers being set up to prevent the sand penetrating too far into the workings.†

W. S. Hall‡ describes the Zollern II. colliery of the Gelsenkirchen Bergwerks Actien Gesellschaft at Merklind, Westphalia, and the method of working. The hoisting, underground haulage, and coal-washing plant are also dealt with.

The open-working of brown-coal beds by means of excavators of special type is described.§

W. Howarth|| describes longwall working at the collieries of the Seeterampore Coal Company at Nursamooda, India.

J. G. Mackenzie¶ describes and illustrates a method of working by longwall in inclined seams a friable gaseous coal at a depth of over 2000 feet at the Drummond colliery, Westville, Nova Scotia.

H. H. Stoek\*\* gives an illustrated description of the methods of working the coal-mines in the Pocahontas region and other coalfields in West Virginia.

F. W. Parsons,†† in dealing with the general conditions of coal-mining in Central West Virginia, gives details of the methods of working at the Coalton Mine of the Davis Colliery Company, where the conditions are typical of those existing throughout the central district.

J. S. Walker‡‡ describes the method of working at the mines of the United States Steel Corporation at Gary, West Virginia.

W. L. Hamilton§§ describes the methods of working adopted in the George's Creek coalfield, Maryland, with the object of reclaiming a

\* *Revue Universelle des Mines*, vol. xxvi. pp. 225-275.

† *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. lvii. pp. 35-38.

‡ *Engineering and Mining Journal*, vol. lxxvii. pp. 1135-1137.

§ *Braunkohle*, April 1, 1909, pp. 8-11.

|| Paper read before the Mining and Geological Institute of India; *Iron and Coal Trades Review*, vol. lxxviii. p. 652.

¶ Paper read before the Nova Scotia Society of Engineers; *Mines and Minerals*, vol. xxix. pp. 491-492.

\*\* *Mines and Minerals*, vol. xxix. pp. 394-400, 471-475, 509-514.

†† *Engineering and Mining Journal*, vol. lxxvii. pp. 1284-1289.

‡‡ *Ibid.*, vol. lxxviii. pp. 6-10.

§§ *Ibid.*, pp. 22-24.

large area of coal which was worked between 1850 and 1885, in such a manner that 60 per cent. of the coal-seam was left unmined and abandoned.

J. E. Sheridan \* describes the methods of working adopted at the collieries of the Stag-Cañon Fuel Company, Dawson, New Mexico. The system of mining is by triple main-entries, double-cross entries, room-and-pillar, and robbing on retreat when the district becomes exhausted. The general rules and regulations adopted by the company for the operation of its mines and the regulation of the workmen are given in full, and the special precautions exercised in shot-firing detailed.

E. K. Judd † describes a novel method of working employed at Kaylor, Armstrong County, Pennsylvania. Rooms are driven with a width of 42 feet, and each room has two necks, each 12 feet wide. The stub pillar has a width of 18 feet and a length of 21 feet. The gob is packed up along the middle of the room. The arrangement greatly facilitates the operation of the electrically driven chain undercutters employed, and the method is advocated wherever circumstances, and, in particular, the existence of a good roof, allow of its adoption.

**Underground Haulage.**—M. B. Mountain ‡ discusses the progress in haulage and winding by electricity in Great Britain.

An illustrated description is given § of the "Cascade" electric motor for haulage and driving purposes in mines.

The advantages of electrical haulage as compared with animal haulage in coal-mines are discussed by F. C. Albrecht. ||

Recent developments in haulage machinery are dealt with. ¶

At the Deister colliery \*\* the surplus power of the 16 horse-power benzine pumping-motor is utilised for operating a haulage incline by coupling a worm shaft on to the main shaft.

Endless rope haulage on inclines has been introduced at several German collieries, †† the brake pulley in one case being placed at the foot of the incline, out of reach, and the rope being held down on a level with the tub top by a vertical roller. One man works the brake and hooks on the tubs.

An illustrated description is given ‡‡ of the Bothwell underground conveyor, together with particulars of the actual working of the conveyor at a colliery in Lanarkshire.

\* *Bulletin of the American Institute of Mining Engineers*, 1909, pp. 537-564.

† *Engineering and Mining Journal*, vol. lxxxviii. p. 453.

‡ *Transactions of the Manchester Geological and Mining Society*, vol. xxxi. pp. 126-152.

§ *Colliery Guardian*, vol. xcvi. pp. 778-780.

|| Paper read before the West Virginia Coal Mining Institute, June 1, 1909; *Engineering and Mining Journal*, vol. lxxxviii. pp. 163-164.

¶ *Iron and Coal Trades Review*, vol. lxxix. p. 53.

\*\* *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. lvii. pp. 61-62.

†† *Ibid.*, pp. 60-61.

‡‡ *Colliery Guardian*, vol. xcvi. pp. 622-623.



Jig-conveyors are used in a number of German collieries \* for delivering the coal from the face to the haulage roads.

Particulars, with illustrations, are given † of various tub stops in use in German collieries for haulage inclines.

Various devices for greasing pit tubs are described ‡ and illustrated, together with self-acting doors in main roads, and the electric block-system used in locomotive haulage at the Shamrock colliery.

**Winding-Engines.**—The most serious drawback to the adoption of electrical operation in connection with hoisting engines has hitherto been the expensive flywheel converter. This difficulty has been overcome by a scheme recently applied for the first time at the Mauve pit winding plant of the Consolidated Heinitz mines at Beuthen, Hungary. The scheme, which is described by A. Gradenwitz,§ utilises a Brown-Boveri-Parsons steam turbine for transmitting any load fluctuations of the winding plant, without the intermediary of converters, directly to the boiler plant, which constitutes an ideal accumulator.

J. Blažek || discusses methods of equalising the load in electric winding-engines, with special reference to the Ilgner flywheel converter.

R. H. Collingham ¶ discusses the mechanics of Ilgner system winding-engines.

J. B. van Brussel \*\* gives a description of a 300 horse-power winding-engine that has been installed in an English colliery. The engine is of the coupled high-pressure type with cylinders 36 inches in diameter and 72 inches stroke. The cylinders are constructed for a working pressure of 150 lbs. and superheat of 50° F. The winding drum is arranged for two ropes, each commencing on a flat 13 feet in diameter, then continuing up a slow core to 14 feet diameter, and running up a spiral to the cylindrical portion of the drum, which is 17 feet in diameter. The distance between the flanges of the cylindrical portion is 7 feet 6 inches in the clear.

An illustrated description is given †† of an electrically operated winding gear lately completed for the Tinsley Park colliery, near Sheffield.

A description is given ‡‡ of winding-engines at the Clifton colliery, Nottingham.

An illustrated description is given §§ of the winding-engine at the Baggeridge colliery. It is of the four-cylinder, duplex, tandem-compound type, designed to raise a net load of coal of 7 tons 4 cwts. from the pit bottom to bank, a distance of 600 yards, in 44½ seconds.

\* *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. lvii. pp. 51-57.

† *Ibid.*, pp. 58-59.

‡ *Ibid.*, pp. 45-50.

§ *Engineering and Mining Journal*, vol. lxxxviii. pp. 74-76.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lvii. pp. 505-510, 524-530, 540-542, 555-557, 567-572.

¶ *Engineering*, vol. lxxxvii. pp. 807-808.

\*\* *Engineering and Mining Journal*, vol. lxxxvii. pp. 904-905.

†† *Colliery Guardian*, vol. xcvi. p. 1129.

‡‡ *Iron and Coal Trades Review*, vol. lxxix. p. 624.

§§ *Ibid.*, vol. lxxviii. pp. 784-785.

W. H. Patchell \* describes the electrical winding plant at the Ferndale collieries.

The equipment of the Kirkby colliery of the Butterley Coal and Iron Company is described † and illustrated.

The electric winding machinery of the Elisabeth collieries, near Charleroi, is described and illustrated. ‡ It is worked by continuous current, and is calculated to raise 600 tons in ten hours from a depth of 400 metres. The balancing apparatus, signalling, and other safety appliances are described in detail.

A twin-tandem steam winding-engine on the Koepe system, recently installed at the Minister Achenbach colliery, is described and illustrated. §

An electric winding-engine, driving a Koepe pulley without any special precaution against rope slip, is in successful operation at the Königsgrube colliery. || At the Beust shaft, Deutschland colliery, a double rope, with two-groove Koepe pulley and tension adjustment, is used to prevent slip.

M. B. Mountain ¶ describes various electrical winding plants in use in Belgium and Germany.

T. Hinton, \*\* in dealing with electric winding in England, discusses the advantages of the electrical hoist over steam-winding.

E. K. Scott †† compares the advantages of direct-current and three-phase motors for winding-engines.

**Winding Appliances.**—The design and construction of colliery cages is described with diagrams and illustrations by N. Dessard. ‡‡

F. Pratt §§ describes a patent safety apparatus for cages, consisting of a clutch or grip for the purpose of arresting the cage in case of an accident in the winding or the breaking of the winding rope. The grips are worked by a bell crank lever, and are brought into action by a weight suspended from the centre of the cage. The descent of the cage would be arrested within a couple of feet.

An illustrated description is given |||| of a safety-catch at the Sydney No. 1 colliery of the Nova Scotia Steel and Coal Company.

T. C. Futers ¶¶ gives an illustrated description of an automatic cage tub stop.

\* *Proceedings of the South Wales Institute of Engineers*, vol. xxvi. pp. 848-916.

† *Iron and Coal Trades Review*, vol. lxxviii. pp. 819-820.

‡ *Génie Civil*, vol. liv. pp. 289-293.

§ *Glückauf*, vol. xlv. pp. 524-525.

|| *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. lvii. p. 62.

¶ *Transactions of the Manchester Mining and Geological Society*, vol. xxxi. pp. 126-152.

\*\* *Engineering and Mining Journal*, vol. lxxxvii. pp. 898-899.

†† *Iron and Coal Trades Review*, vol. lxxix. p. 389.

‡‡ *Revue Universelle des Mines*, vol. xxv. pp. 1-39.

§§ Demonstration before the South Wales and Monmouthshire branch of the National Association of Colliery Managers, September 25, 1909; *Iron and Coal Trades Review*, vol. lxxxix. p. 589.

|||| Report of the Nova Scotia Department of Mines; *Canadian Mining Journal*, vol. xxx. pp. 208-209.

¶¶ *Transactions of the Institution of Mining Engineers*, vol. xxxviii. pp. 109-113.

**Winding Ropes.**—J. Elce \* gives the results of working and testing of a number of locked coil winding ropes installed at the Silverwood colliery in 1906 in place of the ordinary lay ropes.

H. Kroon † gives formulas by means of which the calculation of the strength of wire ropes is simplified.

The experiments conducted by Wagner ‡ on the action of neutral saline solutions, acid water, and warm damp air on the wires of winding ropes, indicate that greasing the rope, if frequently repeated, will prevent corrosion. Purely oxidation influences can be prevented by careful galvanising, but this protection disappears when the zinc coating is corroded by salt water.

C. W. Beers§ gives methods and tables for the calculation of rope strains in hoisting, together with a derived curve which serves for the rapid solution of problems concerning such strains, and can be easily applied by mine foremen and others unable to understand the mathematical principles and formulas upon which they are based.

A. Stör || has calculated the variation of the stresses in winding ropes due to change of winding speed.

The problem of rapid acceleration and deceleration in colliery winding is considered. ¶

**Mine Drainage.**—W. O. Wood \*\* gives an account of the method employed in stopping an extensive leak, under high pressure, in the tubbing of the East Pit at Murton colliery.

S. F. Sopwith †† describes the emergency pumping plant at the Cannock Chase colliery.

The "Cornish" compound duplex quadruple-acting ram pump engine, installed at the Navigation collieries, Crumlin, is described ‡‡ and illustrated. It was designed for a duty of 100,000 to 120,000 gallons per hour, delivered against a head of 500 feet, with a steam pressure of 80 lbs. per square inch, but is equal to delivering the same volume of water against a 600-foot head, with a corresponding steam pressure.

An illustrated description has appeared §§ of an electrically driven pumping plant recently completed for the Chowrassie colliery of the Equitable Coal Company, India.

C. Hanocq |||| deals with the construction and application of centri-

\* Paper read before the Midland Institute of Mining, Civil, and Mechanical Engineers, July 22, 1909; *Colliery Guardian*, vol. xcvi. p. 231.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lvii. pp. 343-347.

‡ *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. lvii. pp. 88-95.

§ *Engineering and Mining Journal*, vol. lxxxviii. pp. 362-363.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lvii. pp. 419-426, 438-442, 455-460, 470-474.

¶ *Electrical Magazine*, vol. xii. pp. 129-131.

\*\* Paper read before the Institution of Mining Engineers, September 15, 1909.

†† Paper read before the South Staffordshire and Warwickshire Institute of Mining Engineers, April 27, 1909; *Iron and Coal Trades Review*, vol. lxxviii. p. 649.

‡‡ *Iron and Coal Trades Review*, vol. lxxix. p. 654.

§§ *Colliery Guardian*, vol. xcvi. p. 1270.

|||| *Revue Universelle des Mines*, vol. xxv. pp. 214-257; vol. xxvi. pp. 276-328.

fugal pumps, and discusses the mathematical considerations underlying their design, and upon which their effective running depends in practice. Tables, diagrams, and formulas for the calculation of dimensions and power requirements are given.

Eichler \* describes the new pumping plant at the Rosenblumendelle colliery.

J. A. Seager † describes how, in a sudden emergency, an inrush of water during mining and sinking operations was successfully dealt with and overcome.

**Mine Ventilation.**—E. Schmid ‡ considers the influence of the rock temperature on the air in mines, and the means for insuring a sufficiently cool air supply at great depths.

J. S. Haldane § enumerates the problems connected with the ventilation of deep mines, and discusses the best method for their solution.

C. Legrand || investigates the subject of mine ventilation from the point of view of the physics of air driving, and the influence of great depths on mine ventilation plant and appliances.

J. G. Smyth ¶ describes a method for the determination and regulation of the percentage of gas in mine air currents. He gives results of investigations carried out by the Fairmont Coal Company.

A description \*\* is given of a device at the Kohlwald colliery for measuring the volume of air traversing a given point in the workings, an octagonal elliptical frame being erected, enclosing a definite sectional area of the gallery and the branched ends of the water-gauge opening at the face of each segment, thus enabling the mean statical depression to be measured with approximate accuracy.

A. H. Stokes, †† in dealing with the subject of water-gauges and air velocities, discusses at length the velocities and pressures of air currents, sets out a number of formulas, and gives the comparative results obtained.

The results are given ‡‡ of tests of a mine fan at the Coppice colliery, Cannock.

The result of a test which was recently made of a Sirocco mine fan installed in the No. 6 pit of the Glamorgan Coal Company is given. §§

E. Stach ||| describes a new method of testing the efficiency of the Hohenzollern fan lately installed at a colliery near Bochum.

\* *Glückauf*, vol. xlv. pp. 1033-1037.

† *Engineering and Mining Journal*, vol. lxxxviii. p. 509.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lvii. pp. 359-362, 460-464.

§ *University of Birmingham Engineering and Mining Journal*, July 1909, pp. 49-57.

|| *Revue Universelle des Mines*, vol. xxvii. pp. 67-98.

¶ Paper read before the West Virginia Coal Mining Institute; *Iron and Coal Trades Review*, vol. lxxix. pp. 169-170.

\*\* *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. lvii. pp. 76-77.

†† *Transactions of the Institution of Mining Engineers*, vol. xxxviii. pp. 132-217.

‡‡ *Iron and Coal Trades Review*, vol. lxxviii. p. 569.

§§ *Ibid.*, p. 613. ||| *Glückauf*, vol. xlv. pp. 913-915.

The new ventilating installation at the Ewald colliery, Herten, Westphalia, is illustrated and described.\* It consists of two Rateau fans, each with a normal output of 374,600 cubic feet per minute, and direct coupled to a 900 horse-power three-phase induction motor.

**Gases in Mines.**—C. Mezger † has studied the connection between the fluctuations in atmospheric pressure and the proportion of foul gases in the air in coal-mines.

A. L. Hodges ‡ discusses the constituents and properties of mine gases.

G. H. Winstanley § describes in detail the properties of the several mine gases.

S. Nauckhoff || describes the results of an investigation into the question of the percentage of carbon monoxide present in the atmosphere of mines, after firing varying weights of charges of dynamite of different composition.

W. Cullen ¶ gives the results of experiments carried out in coal-mines in South Africa in order to determine what gases were produced under actual working conditions by the usual high explosives. A series of gas analyses of mine air were made, and results before and after blasting are given.

W. W. Tunncliffe \*\* considers the properties of mine gases and the means of detecting their presence.

A. de la Ruffie †† discusses the composition, properties, and occurrence of firedamp and the means for preventing accidents due to its presence in mines.

E. Hauser ‡‡ describes a new apparatus for testing firedamp.

**Explosions in Collieries.**—A. H. Stow §§ discusses the possible effects of seismic disturbances on the accumulation of gas in coal and its extension into colliery workings.

The official report of R. A. S. Redmayne ||| and R. D. Bain, respectively chief inspector and inspector of mines, has been issued upon the circumstances attending an explosion on February 16, 1909, at West Stanley Colliery, Durham, which resulted in the loss of 168 lives. From the evidence of the witnesses it appears fairly certain that a small initial explosion was succeeded within about fifty

\* *Mining Journal*, vol. lxxxv. p. 566.

† *Glückauf*, vol. xlv. pp. 1105-1110, 1150-1156.

‡ *Mining World*, vol. xxx. pp. 1063-1064.

§ Lecture delivered before the Lancashire Branch of the National Association of Colliery Managers, September 25, 1909; *Iron and Coal Trades Review*, vol. lxxix. pp. 586-589.

|| *Zeitschrift für das Schiess- und Sprengstoffwesen*; *Journal of the Society of Chemical Industry*, vol. xxviii. p. 816.

¶ *Journal of the Chemical, Metallurgical, and Mining Society of South Africa*, November 1908; *Mines and Minerals*, vol. xxix. pp. 414-415.

\*\* *Mining Engineering*; *Mining World*, vol. xxx. p. 774.

†† *Revue générale de chimie*, vol. xii. p. 105.

‡‡ Paper read before the Seventh International Congress of Applied Chemistry, London.

§§ *Engineering and Mining Journal*, vol. lxxxviii. pp. 449-450.

||| Report on the Explosion at West Stanley Colliery. Cd. 4788.

seconds by a severe explosion which was projected from seam to seam, and was undoubtedly propagated by dust.

An illustrated description is given \* of the results of further experiments carried out during June, July, and September 1909, at Altofts, in connection with the problem of coal-dust explosions in mines.

The standing committee in Vienna for the investigation of colliery explosions † has made arrangements to carry out experiments similar to those recently made by the Royal Commission on coal-mining in the United Kingdom to determine the explosibility of coal dust. Owing to the interest taken in this matter a translation in full of the British Commission's report on their experiments is published.

Czaplinski ‡ and Jičínský describe tests on the explosibility of coal dust carried out in a gallery specially equipped for testing purposes in the Rossitz colliery district, Austria.

W. Pokorný § describes the experimental stations erected in Belgium and Germany for investigating firedamp and coal-dust explosions, and testing explosives.

M. J. Taffanel || gives an illustrated account of the work carried out at the experimental testing station at Liévin. The Liévin testing station has been established by the Central Committee of Collieries of France, with the object of studying questions relating to security in mines and those requiring experimental investigation. Its chief object is to solve the question of the degree of explosiveness of coal dust. An account of the experiments which have been carried out is given. The coal dust investigated was (1) fine dust containing 30 per cent. of volatile matter intimately mixed with fine schist; (2) coarser dust without admixture of schist; both these categories being derived from collieries at Liévin; and (3) fine dust consisting of coal only, containing 24 per cent. of volatile matter, obtained from the Noeux collieries. Out of six tests containing 50 per cent. of schists four gave an explosion, and two became inflamed, but so slowly that they were not able to propagate the explosive wave to the end of the experimental gallery. The experiments would seem to suggest that pure coal dust is less explosive than coal dust mixed with foreign particles.

A series of tests ¶ has been commenced at the United States testing station at Pittsburg to determine the amount of moisture necessary with different coal dusts, to prevent the risk of a coal-dust explosion caused by a blown-out shot of one of the dangerous types of explosives. Coal dust taken from the roads of one of the coal-mines in the Pittsburg district required at least 12 per cent. of water to prevent an ignition. It has also been proved that the finer

\* *Colliery Guardian*, vol. xcvi. pp. 217-221, 675-676.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lvii. pp. 203-209, 225-228, 239-241, 265-267.

‡ *Ibid.*, pp. 535-540, 549-555.

§ *Berg- und Hüttenmännisches Jahrbuch*, vol. lvii. pp. 1-64.

|| *Revue de Métallurgie, Mémoires*, vol. vi. pp. 842-851.

¶ *Colliery Guardian*, vol. xcvi. pp. 431-434.

the dust the more water is required, and dust of 100-mesh fine necessitated 30 per cent. of water to prevent an ignition when the flame of a blown-out shot comes in direct contact with the dust.

H. M. Morgans \* discusses the explosion that occurred at the Norton Hill colliery, Radstock, Somerset, in April 1908.

A. Breyre † discusses the explosions which have occurred in mines and underground workings in Belgium, traceable, directly, to the use of explosives, with special reference to the investigations on the subject carried out by V. Watteyne.

Bellingrodt ‡ reports on the inquiry into the cause of an explosion in an explosives store in the Carolus Magnus pit (West Essen), on July 15, 1908. The cause is ascribed to the suicidal mania of the overman in charge of the explosives, who had obtained a length of fuse (part of which was found on his body) from a shot-firer, for which he had no legitimate use.

Ahrens § describes the investigation of the cause of the firedamp explosion at the Dudweiler colliery on August 10, 1908. The firedamp was liberated from the standing coal by the disturbances caused by working, and penetrated an old road (hitherto free from gas), where it became ignited, probably through the accidental swinging of a lamp with red-hot gauze.

C. J. Coll || considers some of the causes of recent mine explosions, and gives the rules governing shot-firing which are in operation at the mines of the Arcadia Coal Company, Pictou County, Nova Scotia.

R. T. Chamberlin ¶ has investigated explosive mine gases and dusts with special reference to explosions in the Monongah, Darr, and Naomi coal mines in Pennsylvania and West Virginia. In comparing the inflammability of coal dusts he finds that the newly made dust at the working faces of the mine possesses greater explosive potentialities than the old dust along the main haulage ways.

L. D. Tracy \*\* discusses some simple causes of mine explosions. The inability of the average miner in the bituminous mines in the United States properly to understand the dangers involved in his work is well known, and, according to the report of the Pennsylvania Department of Mines, 41·19 per cent. of all the fatal accidents in the bituminous mines were due to the carelessness of the victims themselves, and 36·1 per cent. were due to the carelessness of others. Instances are also given of accidental derangements of ventilation, which, had they not been discovered in time, might have led to serious explosions.

F. Laur †† discusses the phenomena preceding gas explosions, and the circumstances in which dangerous periods for working gassy mines

\* *Engineering and Mining Journal*, vol. lxxxvii. pp. 994-995.

† *Revue Universelle des Mines*, vol. xxv. pp. 97-126.

‡ *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. lviii. pp. 112-119.

§ *Ibid.*, pp. 1-8.

|| *Journal of the Mining Society of Nova Scotia*, vol. xiii. pp. 51-67.

¶ *United States Geological Survey, Bulletin* No. 383.

\*\* *Engineering News*, vol. lxii. pp. 2-4.

†† *Comptes Rendus Mensuels de la Société de l'Industrie Minière*, 1909, pp. 336-357.

may be foretold, and considers the relation of sidereal influences to gas explosions.

Details are given\* of the experiments carried out under the auspices of the Mining Association of Great Britain in connection with the problem of coal-dust explosions in mines.

Forstmann† discusses the method of dealing with the danger from coal dust in the Westphalian coal district, and gives tables of the explosions and their results, and also the fatal accidents due to falls of roof and coal in the Westphalian district for the individual years from 1885 to 1907 inclusive. From the figures in question it would appear that the average deaths per 1000 during the periods 1895–1898 and 1899–1907 dropped from 0·48 and 1·170 in the former to 0·05 and 0·984 in the latter period, the fatalities being due respectively to explosions and falls.

J. Milsom‡ describes methods of dealing with coal dust so as to prevent explosions.

H. N. Eavenson§ discusses the effect of humidity on mine explosions, and points out that it has long been a matter of common opinion among mining men that mine explosions are more frequent during the colder or winter months, when the air is dryer, than during the warmer months. It would appear to be proved that if coal dust by itself is explosive, the removal of a certain amount of moisture from the air in mines apt to be dusty may convert a mine ordinarily safe into one liable to explosion. A table of humidity tests at various mines in South West Virginia, and tables showing the mine explosions supposed to have been caused by gas or dust and attended with five or more fatalities officially reported in North America from October 1871 to March 1908 are given, together with tables showing the incidence of the explosions per month and the average monthly weight of aqueous vapour in air. The figures seem to indicate that more serious explosions do occur during the colder or low humidity months than during the warmer ones, but that the disproportion is not so great as is usually supposed. The opinion is expressed that whatever may be the effect of moisture on gas or dust explosions, they could nearly all be prevented by effective ventilation or sprinkling.

J. Taylor|| discusses colliery explosions and their causes. He considers that sufficient attention is not always given to the prevention of the production of coal dust and its accumulation, and that this object can only be attained by a proper system of mining, and constant and efficient cleaning of roadways, in preference to the adoption of such systems of sprinkling as are now generally advocated.

\* *Iron and Coal Trades Review*, vol. lxxix. pp. 157–158.

† Paper read before the Seventh International Congress of Applied Chemistry, London.

‡ *Journal of the British Society of Mining Students; Iron and Coal Trades Review*, vol. lxxix. p. 348.

§ *Bulletin of the American Institute of Mining Engineers*, 1909, pp. 567–578.

|| Paper read before the Illinois Fuel Conference, Urbana, Illinois, March 12, 1909; *Engineering and Mining Journal*, vol. lxxvii. pp. 1191–1192.



J. Verner \* discusses the mechanical influence of air-currents in furnishing conditions favourable to coal-dust explosions. It is generally assumed that coal dust is the prime factor in a dust explosion, but the author considers that of the three factors upon which an explosion depends, namely, the initial flame, air, and dust, the latter is the least important.

H. Hall † discusses the question of coal dust in mines. The efforts of the early investigators on the subject of coal-dust explosions are reviewed, and a description is given of the experiments carried out by the author in 1890 in a disused colliery shaft 150 feet deep. A summary of the conclusions of the Royal Commission on explosions in coal-mines, appointed in 1891, is also given.

F. Bache ‡ discusses the possible sources of explosions in mines, and lays stress on the fact that as coal dust appears to be the chief source, the best way to prevent such explosions is to remove the dust.

P. P. Bedson § discusses the inflammability of mixtures of air and coal dust.

H. Hall || recommends the use of calcium chloride for laying dust in coal-mines, the salt being used either in the form of concentrated solution (48° to 50° Twaddell), or as a fine dry powder in seams where watering cannot be resorted to. It is stated that one application of the salt every three months is sufficient.

Graefe ¶ has investigated the inflammability of brown-coal dust of various kinds, and the possibility of its ignition by means of the electric incandescent lamp. Under normal conditions there is no risk, provided the lamps are protected with wire netting.

Explosions in switch-boxes, and sparking inside a switch, are discussed by S. F. Walker \*\* as possible causes of colliery explosions.

J. Ashworth †† points out some of the dangers attending the use of electricity in coal-mines, and the part it has played in causing explosions.

**The Lighting of Collieries.**—M. H. Mills †‡ deals with the use of electric lamps for miners, with special reference to the "Float" lamp, and enumerates some of the advantages which a reliable electric lamp for miners would have over the present oil safety lamp.

R. Cremer §§ gives a description of the Wolf-Bohres electric safety lamp.

\* *Mines and Minerals*, vol. xxix. pp. 466-469.

† *Engineering and Mining Journal*, vol. lxxxvii. pp. 1084-1089.

‡ *Bulletin of the American Institute of Mining Engineers*, 1909. pp. 741-747.

§ Paper read before the Seventh International Congress of Applied Chemistry, London.

|| *Transactions of the Mining Institute of Scotland*, vol. xxxi. pp. 96-118.

¶ *Braunkohle*, May 1, 1909, pp. 105-111, 125-129.

\*\* *Engineering and Mining Journal*, vol. lxxxviii. pp. 166-167.

†† *Ibid.*, pp. 123-124.

‡‡ Paper read before the Midland Counties Institution of Engineers, April 1909; *Colliery Guardian*, vol. xcvi. p. 875.

§§ Paper read before the North of England Institute of Mining and Mechanical Engineers.

S. Icard \* discusses the lighting of safety lamps.

J. B. Marsaut † discusses the more important types of safety lamps at present in use in collieries.

The glassworks at Baccarat (France) have prepared a new glass containing 75 per cent. of sand, 13 per cent. of sodium bicarbonate, 9 per cent. of magnesium carbonate, 6 per cent. of zinc oxide, and 5 per cent. of red lead. This glass will not crack when heated to 100° C. and sprinkled with water at 15° C., or when heated for five minutes in a flame. These tests were applied by G. Chesneau, chief engineer to the Department of Mines, and in consequence of the favourable results obtained, the glass has been adopted by the French Government for the chimneys of safety lamps, as being superior to Jena glass for that purpose. ‡

Experiments have been made at the Neunkirchen colliery (Saar) § with lamp glasses of Jena glass and of Val-St.-Lambert glass. The Jena glass and one brand (D4S) of the Belgian glass behaved best in the quenching and impact tests, and in tilted lamps. Practical trials with the Jena glass in the pit showed a considerable saving in the cost of renewal as compared with ordinary glass.

J. Mayer || has carried out an extensive series of tests on cerium iron and other new ignition devices for mine lamps, with a view to establishing their safety in the presence of firedamp.

V. Watteyne ¶ and E. Lemaire have tested the safety of the cerium-iron igniter introduced for lighting safety lamps, and confirm the judgment already passed by German and Austrian experimenters, namely, that numerous fine particles of the ferro-cerium are projected on and through the gauze, and form a source of danger as regards the ignition of firedamp. In spite of its defects, the phosphorus pellet igniter on paraffin-steeped ribbon is the only system possessing the requisite qualities for safety in fiery mines.

Sir H. H. Cunynghame \*\* and J. C. Cadman describe, with illustrations, an appliance adaptable to ordinary miners' lamps for the detection of firedamp.

E. B. Whalley †† and W. M. Tweedie deal with the detection of firedamp in mines by means of safety lamps.

G. R. Thompson ‡‡ gives details of an equipment for the study of flame caps and for miscellaneous experiments on safety lamps.

**Underground Fires.**—H. H. Stook §§ describes the method of sealing off the fire at the Summit Hill mine of the Lehigh Coal

\* Paper read before the Seventh International Congress of Applied Chemistry, London.

† *Bulletin de la Société de l'Industrie Minérale*, vol. x. pp. 217-242.

‡ *Colliery Guardian*, vol. xcvi. p. 81.

§ *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. lvii. pp. 72-75.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lvii. pp. 219-225, 242-244, 261-265, 279-282, 300-303.

¶ *Annales des Mines de Belgique*, vol. xiv. pp. 707-723.

\*\* *Colliery Guardian*, vol. xcvi. pp. 774-775.

†† Paper read before the Institution of Mining Engineers, September 15, 1909.

‡‡ *Ibid.*

§§ *Mines and Minerals*, vol. xxx. pp. 1-5.

and Navigation Company, Pennsylvania. The fire in question was discovered on February 15, 1859, and has been burning continuously ever since in spite of several efforts to extinguish it. The present attempt consists of sinking a line of shafts, removing the coal and rock, and filling the space with clay to form a barrier.

J. A. Garcia\* describes a method of sealing off the shafts at mine No. 18 of the Dering Coal Company, Franklin County, Illinois, in an attempt to extinguish a fire caused by explosion.

A barrier of sandbags, for temporarily shutting off parts of the workings in the event of a pit fire, has been successfully tried at the Hedwigs Wunsch colliery.† A double wall of the bags is set up, and the interstitial spaces are filled with loose sand, a barrier of 320 bags being completed in two hours.

A. G. Morse‡ deals with the extinction of fires in mines, and advocates the use of chemicals, but not of sulphur dioxide, in combating such occurrences

**Accidents in Mines.**—A report has been issued§ by the Committee appointed by the Royal Commission of Mines to inquire into the causes and means of preventing accidents from falls of ground, underground haulage, and in shafts. Since the date of the committee's appointment in January 1908, thirty-one collieries have been inspected. The statement for the last decennial period shows that the percentage of accidents was: Falls of ground, 57·8; haulage, 22·6; shafts, 8·8; other causes, 10·8. The number of persons employed below ground in 1907 was 757,887, and the number of deaths due to accidents was: Falls of ground, 574; haulage, 245; shafts, 98; other causes, 142—total, 1059. Obviously it is in the direction of the more effective support of the roof and sides, and in improved methods of working, that the greatest hope of further diminution in mine fatalities lies. It is recommended that a universal code be adopted for signalling in shafts. The committee considers that haulage which allows of a slow rate of travel and regular feed to the shaft is more conducive to safety than spasmodic feed and hence high rate of travel.

The prevention of accidents in coal-mining is discussed by E. H. Coxе.|| He classifies the accidents likely to occur into four categories: (1) those caused by explosions which could be avoided by dust and gas elimination, for which the use of the Lechler spray is advocated, together with a well-organised system of electrical shot-firing; (2) accidents caused by fall of rock and coal often caused by bad timbering and inadequate inspection; (3) accidents caused by defective or improperly protected machinery or appliances; and (4) all other

\* *Mines and Minerals*, vol. xxx. pp. 59–62.

† *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. lvii. pp. 77–78.

‡ Paper read before the West Virginia Coal Mining Institute, June 1, 1909; *Engineering and Mining Journal*, vol. lxxxviii. p. 166.

§ Cd. 4821.

|| *Engineering and Mining Journal*, vol. lxxxviii. pp. 410–413.

accidents of a miscellaneous nature which may again be traceable to the foregoing causes.

H. Johnstone\* deals with the subject of accidents in mines.

C. H. Hair† classifies the nature of mine accidents, and gives a number of suggestions as to the rendering of first aid.

Stegemann‡ describes the precautions enforced by the authorities of the Aix mining district in watery or fiery mines against sudden inrushes of water or instantaneous outbursts of firedamp. Holes  $1\frac{1}{2}$  inch in diameter are drilled horizontally to a depth of 15 feet in advance of the working face and also in the roof and foot rock to a depth of about 5 feet, the latter holes sloping at an angle in the direction of working. On tapping fissures containing water or gas it is possible to get the escape immediately under control.

J. Elliott§ describes a peculiar accident that occurred at the mine of the Bailey-Ola Company, Baileyville, Oklahoma. The mine generates considerable explosive gas; the dust is of a highly inflammable character, and the mine is very dry. The accident originated in the following manner. Tubs filled with black lubricating oil are taken to the bottom of the shaft and placed between two tracks, and as the empty cars are taken from the cage their oil-boxes are filled from the tub containing the lubricating oil. On the occasion of the accident in question one of the miners had taken his lamp off his cap and had lowered his hand until the light was within 12 to 15 inches of the tub, when what was believed to be gas from the lubricating oil was ignited. The flames spread, owing to the tipping of the tub, and in a short time all the supports inward for about 100 feet had been consumed up to the point where the slope started from the main level, letting down 1000 tons of rock. On investigation of the oil supply from which the oil for lubricating was taken it appeared to be similar to the ordinary black oil used in mines for lubricating purposes, but was found on analysis to be crude petroleum.

V. Watteyne|| and A. Breyre continue their account of the accidents due to explosives in Belgian mines from 1893 to 1907, and in conclusion describe the precautions to be adopted for the prevention of misfires or in the event of their occurrence, and detail also the special dangers attending the various categories of mine explosives and methods of shot-firing, and the measures advised for the prevention of accidents therefrom.

**Life-saving Appliances.**—The Technological branch of the United States Geological Survey,¶ in co-operation with the Illinois Geological Survey and the College of Engineering of the University of Illinois,

\* Presidential Address delivered before the South Staffordshire and Warwickshire Institute of Mining Engineers, October 12, 1909; *Iron and Coal Trades Review*, vol. lxxix. p. 622.

† Paper read before the Canadian Mining Institute.

‡ *Glückauf*, vol. xlv. pp. 617-622.

§ *Mines and Minerals*, vol. xxix. p. 488.

|| *Annales des Mines de Belgique*, vol. xiv. pp. 49-234.

¶ *Mining World*, vol. xxx. p. 485.

has installed at the University at Urbana a branch station for instruction in mine rescue work and for the investigation of mine accidents. The equipment consists of a gas-tight room into which noxious gases can be introduced, and of oxygen helmets and other rescue appliances.

R. Grimshaw \* describes experiments carried out with four different types of life-saving apparatus with a view to determining how much work a man equipped with such apparatus could do, and the condition of the air delivered to him.

W. E. Mingramm † discusses the serviceableness of various types of breathing appliances for use in mines.

G. Ryba ‡ contributes to the discussion to which F. Hagemann's criticisms of certain of the latest types of breathing apparatus has given rise.

S. Stassart § and J. Bolle give descriptions of the various types of life-saving appliances proposed for use in mines, and also describe the rescue stations already established in Germany, Austria, England, Canada, Belgium, and Russia. The method of training the men in the use of these appliances at the Frameries station is also detailed, together with a comparison of the different appliances used there. The article concludes with the text of the various regulations issued on the provision of life-saving appliances, and a comparative summary of those in use of the different countries.

F. Jüngst || gives an historical account of the use of breathing apparatus in mines. The first record of such appliances occurs in a report by V. Löhneyss, dated 1690, on some mining works near Gosslar. Illustrations of apparatus used during the eighteenth century are given.

J. Robertson ¶ discusses the use of oxygen in mining accidents, and, after enumerating the lessons derived from rescue work in a flooded pit, arrives at the following conclusions: (1) that an oxygen supply is an absolute necessity in mining operations; (2) that the men ought to be trained in its uses; and (3) that a knowledge of its properties and uses should form a part of the qualifications for a manager's certificate.

G. Claude \*\* deals with the liquid air rescue apparatus.

An illustrated description is given †† of the "Livo" breathing apparatus.

\* *Engineering and Mining Journal*, vol. lxxxvii. p. 1192.

† *Bi-Monthly Bulletin of the American Institute of Mining Engineers*, 1908, pp. 561-570.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lvii. pp. 486-488, 497-502, 510-515, 530-532, 542-545, 557-560, 572-575, 586-588.

§ *Annales des Mines de Belgique*, vol. xiv. pp. 519-706.

|| *Glückauf*, vol. xlv. pp. 833-844, 875-891.

¶ Paper read before the Stirling Branch of the British Medical Association; *Colliery Guardian*, vol. xcvi. p. 877.

\*\* Paper read before the Seventh International Congress of Applied Chemistry, London.

†† *Iron and Coal Trades Review*, vol. lxxviii. p. 628.

**Rescue Work in Collieries.**—Sir H. H. Cunynghame,\* in a lecture before the University of Birmingham, gave an account of the development of rescue work in mines, and demonstrated the inflammability of certain kinds of dust and fine coal dust by blowing them into a flame.

S. Stassart† and J. Bolle give an illustrated description of the Frameries Rescue Station, which has been installed and equipped by the Belgian Government.

An illustrated description has appeared‡ of a large safety barrier recently erected at the Heinitz colliery, Upper Silesia.

**Signalling in Collieries.**—The application of electricity to the transmission of signals in collieries is discussed,§ and various types of the Siemens system are described and illustrated.

A new shaft-signalling device is used at the Deister colliery,|| the signal cord drawing down a rod carrying a lug that operates a tilting lever connected with the striker. A special arrangement of springs is provided for pushing the rod up again. A device for facilitating loading and emptying the cage at the pit bottom has been installed at the Viktoria Pit (Saar), and saves the labour of two men in each shift.

R. Rutherford¶ describes the electric shaft-signalling apparatus at the Mainsforth colliery.

**Sanitation in Collieries.**—The new shower-baths and lavatories at the Artistes pit, Kessales-Artistes colliery, are described by Viatour;\*\* and Fourmarier†† gives a description of the similar installation at the No. 2 pit, Gosson-Lagasse colliery. Other installations of the same character at the Abhooz and Bonne-Foi-Hareng, Milmort, and Bonne-Espérance collieries are described by Raven.‡‡

A. L. Hodges§§ enumerates the diseases peculiar to workers underground, and mentions the means of prevention and methods of treatment.

**Economics of Coal-Mining.**—An article has appeared||| on the risks and profits of colliery owners and the effects of recent legislation. The increased risk owing to the exhaustion of the more accessible beds is dwelt upon; the increase of slack and consequent diminution of profit, owing to the enforced use of explosives, the

\* *University of Birmingham Engineering and Mining Journal*, July 1909, pp. 41-48.

† *Annales des Mines de Belgique*, vol. xiv. pp. 519-706.

‡ *Iron and Coal Trades Review*, vol. lxxviii. p. 894.

§ *Ibid.*, vol. lxxix. pp. 277-278.

|| *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. lvii. p. 65.

¶ Paper read before the National Association of Colliery Managers, May 1, 1909; *Iron and Coal Trades Review*, vol. lxxviii. p. 772.

\*\* *Annales des Mines de Belgique*, vol. xiv. pp. 774-776.

†† *Ibid.*, pp. 776-780.

‡‡ *Ibid.*, pp. 784-796.

§§ *Mining World*, vol. xxxi. p. 173.

||| *Engineer*, vol. cvii. pp. 519-520.

increase of working expenses caused by the Coal Mines Regulations Acts of 1872, 1887, 1902-3, by the Workmen's Compensation Act, and by the Eight Hours Act are also dealt with; and in conclusion a considerable advance in the price of coal is foretold, which will seriously affect the iron and steel industry.

H. M. Chance\* discusses coal-mining as an investment. As the value of coal is independent of special uses or of widely fluctuating demand, investments in coal lands or in coal-mining operations should possess important elements of stability and security. By many, however, they are regarded as speculative or semi-speculative, and quite unsafe as investments. These opposite points of view are considered in detail, and the causes responsible for failure and the factors essential to success discussed. The public is not well informed as to coal-mining profits, grossly exaggerated ideas of the profits of the industry being entertained, whereas in reality the average profit is small. Generally speaking, notwithstanding adverse circumstances, no safer investments can be found in the United States than in bituminous coal-bearing lands.

E. Jüngst† considers the effect of the use of coal-cutting machinery in the Ruhr district on the cost of labour, with special reference to the question of Polish immigration.

**History of Coal-Mining.**—E. W. Parker‡ states that the first bituminous coal mined in the United States was taken from what is usually termed the Richmond Basin, a small area in the south-western portion of Virginia, near the city of Richmond. The occurrence of coal was known there as early as the year 1700, and in 1789 shipments were made to some of the northern States. In 1822 the production amounted to 48,214 tons, but at the present time the small quantity of coal that is produced is for local consumption only.

J. W. Paul§ discusses the development of coal-mining in Europe during the last thirty years.

## IX.—COAL WASHING AND SCREENING.

**Coal-Screening.**—The screening and washing plant of the No. 3 pit of the Bwlfa colliery, near Aberdare, is described|| and illustrated.

To prevent the dissemination of coal dust at the screening plant, the Hultschin colliery¶ has provided a number of exhaust fans, which

\* *Engineering and Mining Journal*, vol. lxxxviii. pp. 316-318.

† *Glückauf*, vol. xlv. pp. 969-976.

‡ *Mineral Resources of the United States*, 1908; *Engineering News*, vol. lxii. p. 217.

§ Paper read before the Coal Mining Institute of America; *Canadian Mining Journal*, vol. xxx. pp. 428-429.

|| *Iron and Coal Trades Review*, vol. lxxix. pp. 308-309.

¶ *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. lviii. p. 80.

draw off the suspended dust and deliver it into a tower, where it is precipitated by means of steam and water sprays.

**Coal-Washing.**—A. W. Belden,\* G. R. Delamater, and J. W. Groves have carried out washing tests of coal to determine the possibility of improving the quality for coking purposes. Fourteen samples of coal, from Colorado, Montana, New Mexico, and Utah were tested at the fuel-testing plant at Denver, and tests show that many coals which are not supposed to be of value for coking may be rendered so by proper treatment in the washery.

G. R. Delamater † discusses the control of coal-washing plants, and describes the work accomplished in the development of control apparatus, and the improvement that has been made, not only in the apparatus used, but in the results obtained, and in the convenience of the methods employed by the Washery Section of the United States Geological Survey.

R. Bolling ‡ discusses methods for the chemical control of coal washing.

The process of coal washing is reviewed by C. C. Myers.§ He enumerates the chief impurities and their specific gravities, pointing out that all coal-washing operations are based on the fact that the density of the impurities is higher than that of the pure coal.

At the Brefeld colliery || the culm from the picking belts and coal washery is put through a supplementary washer, treating about 24 tons and recovering about 6 tons of boiler fuel, with 25 per cent. of ash per day, the residue being used for water-flush packing in the goaf.

L. Fraser ¶ gives an illustrated description of a coal washer that has been installed at the mines of the Consolidated Coal Company, Saginaw, Michigan. Conditions prevailing in the mines make it impossible to deliver a uniform grade of slack coal, the ash percentage fluctuating between 3 and 40 per cent., and averaging about 15 per cent.; but under present operating conditions 18 per cent. by weight of the raw coal is removed in washing, and the coal is separated, in washing, into a nut size, passing over a 1-inch perforation, and a fine coal, both passing over and through a  $\frac{1}{4}$ -inch perforation. The under-size from the  $\frac{1}{4}$ -inch perforation is re-washed in Lührig jigs, and then mixed with the oversize from the  $\frac{1}{4}$ -inch screen. The resulting fine coal contains 5 per cent. of ash, while the nut coal contains 2 per cent. of ash.

The coal-washing plant of the Stag Cañon Fuel Company, Dawson, New Mexico, is described and illustrated by J. E. Sheridan.\*\* The capacity of the plant is 2500 tons a day of ten hours.

\* *United States Geological Survey, Bulletin No. 368.*

† *Mines and Minerals*, vol. xxx. pp. 55-58.

‡ *Eisen Zeitung*, vol. xxx. pp. 454-455.

§ *Sidley Journal of Engineering*, vol. xxii. pp. 245-248; *Mining World*, vol. xxx. p. 486.

|| *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. lvii. p. 80.

¶ *Engineering and Mining Journal*, vol. lxxxvii. pp. 993-994.

\*\* *Bulletin of the American Institute of Mining Engineers*, 1909, pp. 546-554.



W. O. Rogers \* deals with the operation of washeries in the anthracite regions of Pennsylvania—by means of which immense quantities of fuel are recovered from the large banks of culm and waste which exist there—and gives an illustrated description of the No. 2 washery of the Kingston Coal Company at Kingston, Pennsylvania.

**Coal-Handling.**—An illustrated description has appeared † of the coal-handling plant of the Virginia Railway Company at Sewell's Point, Virginia. The mechanical plant comprises a hoist for raising the gondola cars up an incline to a car dumper, which bodily pours the coal into electrically operated hopper-bottom transfer cars. These are in turn hoisted up an incline, and then proceed to the stationary hoppers on the pier into which they are discharged, and from which coal is loaded directly into ships. The pier, which is 1860 feet in length, is of steel, resting on concrete foundations, and the plant is capable of handling 150,000 tons in ten hours, or 4,500,000 tons per year of 300 working days. There will eventually be four such installations, giving a capacity of 18,000,000 tons per year.

D. A. Patterson ‡ describes the coal-handling plant of the Keokee Coal and Coke Company, Virginia.

An illustrated description is given § of the hydraulic coal-handling equipment at the Garston Docks.

An illustrated description is given || of the 30-ton coal tip hoist erected at the South Dock, Swansea.

An illustrated description is given of an electrically operated wagon-tipping plant for the discharge of coal from railway wagons. ¶

Recent types of coal elevators culminating in the rotary feed system designed by Bennis & Co., Limited, are described and illustrated. \*\*

C. K. Baldwin †† describes automatic feeders for handling material in bulk. Illustrations of various feeders are given.

H. Hermanns ‡‡ discusses a number of transport appliances of recent construction for the conveyance of material in bulk from point to point. Illustrated descriptions are given of apparatus on the continuous-band and bucket systems.

An illustrated description §§ is given of the aerial ropeway in use at the Silverwood colliery, near Rotherham.

An illustrated description is given ||| of the Bleichert Ropeway system for the transport and dumping of material.

\* *Power*, vol. xxx. pp. 1053-1058.

† *Iron Age*, vol. lxxxiv. pp. 247-249.

‡ *Canadian Mining Journal*, vol. xxx. pp. 390-392.

§ *Iron and Coal Trades Review*, vol. lxxviii. pp. 765-766.

|| *Ibid.*, vol. lxxix. p. 273.

¶ *Electrical Review*, vol. lxxv. pp. 34-35.

\*\* *Engineer*, vol. cvii. pp. 564-565.

†† *Journal of the American Society of Mechanical Engineers*, vol. xxxi. pp. 605-613.

‡‡ *Stahl und Eisen*, vol. xxix. pp. 1340-1346.

§§ *Iron and Coal Trades Review*, vol. lxxix. p. 93.

||| *Colliery Guardian*, vol. xcvi. pp. 413-415.

Nahnsen \* gives an illustrated description of the machinery and equipment at some Upper Silesian collieries for the transport of coal and rubbish.

W. N. Twelvetees † gives an account of the development of conveyors for the continuous handling and transport of materials.

S. B. Peck ‡ reviews, with illustrations, the various continuous methods for the conveyance of materials.

G. E. Titcomb § describes, with illustrations, many of the intermittent types of hoisting and conveying machinery.

E. J. Haddock || describes, with illustrations and tables, results of experiments made in connection with the performance of belt conveyors.

G. F. Zimmer ¶ describes, with illustrations and tables, belt conveyors for handling various materials including coal.

J. R. Shays \*\* describes, with illustrations, various types of ash-, coal-, and coke-handling equipment for gas plants.

**Coal Briquettes.**—The use of coal briquettes as fuel for locomotives has been dealt with by C. T. Malcolmson.†† The history of coal-briquetting is shown to date back to 1594, although the first successful machine was not built until 1842. The first briquetting plant in the United States was installed at Port Richmond, Philadelphia, in 1870, and was of the Belgian roll type; it used a mixture of 92 per cent. of anthracite culm and 8 per cent. of clay as binder. Various materials and compounds have been tried as the binding medium to unite the particles of pulverised fuel in a hard mass; but it is stated, however, that except in special instances pitch alone is used. It is essential that the amount should be reduced to a minimum, and in American practice the amount varies from 5 to 10 per cent. according to the process used and the character of the coal. Briquettes for locomotives, made by a Schorr press at Stockton, California, were used on the San Francisco and Joaquin Valley Railway. The briquettes were made from lignite mixed with screenings of bituminous coal, and asphalt residuum from Californian petroleum was used as a binder. They weighed from 6 to 9 ounces each, and are stated to have given satisfaction. Details are given of railway experiments with coal briquettes carried out under the direction of the United States Geological Survey.

C. L. Wright ‡‡ gives a detailed account of the manufacture of coal briquettes and of official tests of the briquettes as locomotive fuel.

\* *Glückauf*, vol. xlv. pp. 1361-1372.

† *Engineering Review*, vol. xx. pp. 178-197.

‡ *Transactions of the American Society of Mechanical Engineers*, vol. xxx. pp. 155-186.

§ *Ibid.*, pp. 123-154.

|| *Ibid.*, pp. 217-231.

¶ *Cassier's Magazine*, vol. xxxvi. pp. 354-366.

\*\* *Power*, vol. xxxi. pp. 368-370.

†† Paper read before the International Railway Fuel Association, June 21, 1909; *Engineering News*, vol. lxii. pp. 157-158.

‡‡ *United States Geological Survey, Bulletin No. 385.*

E. Nyström,\* in his report on the uses and manufacture of peat and lignite in Europe, describes the methods employed for the manufacture of briquettes of these products.

In the production of ovoid briquettes from moist fines at the Adler colliery,† liquid naphthalene is being successfully used as a binder in place of pitch.

A device, used at the Elisabeth mine,‡ for removing and consolidating the dust formed in making brown-coal briquettes is described.

\* *Canada, Department of Mines*, Ottawa, 1908.

† *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. lvii. p. 82.

‡ *Ibid.*

# PRODUCTION OF PIG IRON.

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### I.—BLAST-FURNACE PRACTICE.

**Blast-furnace Construction.**—F. Firmstone \* describes the progress in blast-furnace practice in the Lehigh Valley as shown by the furnaces at the Glendon Ironworks. The earliest furnace in the Lehigh Valley was blown in in 1844 for the smelting of iron with anthracite. A section and dimensions of this early furnace are given. The first hearth was of sandstone, but later it was made of firebrick. As the work increased larger furnaces were built and the number of tuyeres was increased. Modifications of the internal design and the adjustment of the tuyere to the varying nature of the materials charged is shown in a series of diagrams which represent the changes made from the earliest period to the latest date of the blowing in, which was 1882. The comparison includes the figures corresponding to weekly make, fuel consumption per ton of pig iron, blast temperature and pressure, and the number of the tuyeres. The furnace blown in in 1844 made 52·3 tons of iron weekly, with a fuel consumption of 2·28 tons per ton of pig iron made. The blast pressure was 4 lbs. and the temperature 500° to 600°, while the number of tuyeres was three. Compared with these figures, the advance as far back as 1882 is striking; the weekly output of iron had risen to 412·4 tons, the fuel consumption was 1·21 tons of coke per ton of pig iron made, and the blast pressure had risen to 9 lbs., the temperature being 800° to 850°. The number of tuyeres in the later furnace was seven.

J. E. Johnson, jun.,† deals with the disadvantages of the standard bosh plate construction with removable bronze plates, and describes

\* *Bulletin of the American Institute of Mining Engineers*, 1909, pp. 821–836.

† *Iron Age*, vol. lxxxiii, pp. 1424–1425.

an improved form of construction which, it is claimed, will obviate these disadvantages. This improvement consists briefly of curved bosh plates. As a result of this construction the brick on the under side of the plates is so protected that it is impossible for it to wear away to any considerable extent, while the surface presented to the furnace after the nose of the bricks has worn away is not a sharp ledge but a smooth surface with a slope virtually identical with that of the original bosh wall. The subject is also dealt with by B. F. Burman.\*

By the following improvement in blast-furnaces adopted by the Lackawanna Steel Company, of Buffalo, and the Illinois Steel Company, of South Chicago, it is claimed that the life of such furnaces is doubled. The entire end blocks of the furnace—ports and downtakes—are built of ground magnesite, with 15 per cent. of ground basic slag, and sufficient coal-tar to make it pack well. The usual gas port arch is replaced by a water-cooled boiler-plate hood, which rests 12 inches on each side of the port on the magnesite bank covering the entire port. This hood has an insulation of ground magnesite on its upper side so that all seams are protected from the flame. The hood is carried forward over the port only to a point from 3 to 5 feet from the block, forming a mixing chamber for the gas and air before they enter the combustion chamber proper over the hearth, thus serving to secure the greatest efficiency and fuel economy of which the furnace is capable. This water-cooled hood in place of the brick arch is the principal feature of the improvement. The bulkhead consists of a plate-box similar to the hood, cooled by the water overflow from the port hood, and forming that part of the back wall of the gas port which ordinarily burns out most rapidly.†

A. O. Baer ‡ and A. G. Witting have designed a safety explosion valve for blast-furnaces, which although permitting a free escape of gas, prevents any of the coke or ore being thrown out when the furnace slips. The valve is a double-acting combined disc and bell valve, the disc forming the valve proper. The bell, which is bolted to the disc and projects into the downcomer, is provided with lugs which, when the valve is lifted by the internal pressure, stop it before it reaches the valve seat, thus keeping the valve open. A sectional view of the valve is given.

**Blast-furnace Practice.**—J. E. Johnson, jun.,§ describes and illustrates a new method of distributing the charge in a blast-furnace, the bell being rotated when empty so that it will charge in a different direction each time. An unsymmetrical bell is used.

**Smelting Magnetic Ore in the Blast-furnace.**—F. E. Bachman || gives the results for three years of the use of all magnetic ore

\* *Iron Age*, vol. lxxxiii. pp. 1700-1701.

† *Times Engineering Supplement*, May 26, 1909, p. 19.

‡ *Iron Trade Review*, vol. xlv. p. 1079.

§ *Iron Age*, vol. lxxxiii. pp. 11488-1498.

|| *Ibid.*, pp. 1438-1439.

in the furnace of the Northern Iron Company at Port Henry, New York. Dealing with the question of smelting titaniferous magnetites, the author states that careful investigation and tests have shown that ore from the Tabawns deposit in the Adirondacks will concentrate to a 58 to 60 per cent. ore with less than 0.01 per cent. of phosphorus, appreciable amounts of vanadium and nickel, and titanium not exceeding 6 per cent. The concentrates produced are somewhat coarser than the Mineville product.

**Smelting Chrome-iron Ores.**—P. Monnartz\* describes the smelting of chrome-iron ores in the blast-furnace with a blast enriched with oxygen. A product containing a high percentage of chromium can be easily obtained with a high pressure of blast and a high temperature. The experiments were on a small scale and yielded an alloy containing about 66 per cent. of chromium.

**Value of Fuel in Blast-furnaces.**—J. von Ehrenwerth† points out that in comparison with the analyses of the materials actually charged, the analysis of the gas issuing from the throat of the blast-furnace shows higher percentages of hydrogen and of hydrocarbides. From this it follows that these gases, whether they enter with the fuel charged or with the other materials, are not burned, and that the whole of the heat evolved is derived solely from the combustion of the solid carbon charged. Formulas and calculations based on this view are given, and certain suggestions and theories put forward with a view to obtaining a better heat balance and more efficient fuel consumption.

T. J. Vollkommer‡ discusses the relative efficiency of various methods of combustion.

**Rate of Combustion in Blast-furnaces.**—M. A. Pavloff§ points out that although it is an axiom of modern blast-furnace practice that the section of the hearth at the tuyere level must be in proportion to the amount of air blown into the furnace, very little information is contained in text-books or technical memoirs on the subject, while such statements as can be found do not agree with the results in actual practice. The statement often made that charcoal, owing to the larger surface it exposes to the blast, permits of a more rapid rate of consumption than coke, and hence a higher duty per square foot of hearth area, is contested as contrary to practical experience. Swedish blast-furnaces working with charcoal show a rate of combustion as low as 1500 lbs. per square foot, while the largest American blast-furnaces using charcoal have shown consumptions

\* *Metallurgie*, vol. vi. pp. 160-167.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lviii. pp. 581-584, 598-602.

‡ *Iron Age*, vol. lxxxiii. pp. 1426-1428.

§ *Ibid.*, vol. lxxxiv. pp. 618-619.

attaining 5200 lbs. of charcoal per square foot of hearth area. In coke blast-furnaces the extreme figures have been 6550 and 3420 lbs. per square foot, the maximum occurring in American practice. A table showing dimensions, general conditions of working, and rate of combustion of fuel for forty modern blast-furnaces is given, the figures relating to twelve charcoal furnaces, and the remainder to coke furnaces running on various grades of iron.

**Blast Pressure.**—R. H. Sweetser \* gives an account of a test made at the East furnace of the Columbus Iron and Steel Company, Ohio, to ascertain whether there was any difference in blast pressure at the different tuyeres. The sources of error likely to vitiate the results of such investigations are discussed, and some of the provisional conclusions to be drawn from the experiments are indicated.

**Dry Air Blast.**—The report of the Franklin Institute on the Gayley dry air blast, an investigation of which has been carried out by a committee of that society, has been published.† The advantages claimed for the process, all of which have been sustained, are summarised, and there are also given a report on the working of the Isabella Furnace in 1907 at E. & G. Brooke Iron Company, Birdsboro', Pennsylvania, together with its effect on the silicon and sulphur content of the iron produced, and still later reports on its application at the Cardiff works and at the Warwick Iron and Steel Company's furnace at Pottstown, Pennsylvania.

R. W. Raymond ‡ discusses the dry air blast process with special reference (1) to the novelty or otherwise of Gayley's invention, and (2) to the specific reasons for the economy arising, in practice, from its adoption. The advantages of removing moisture from the blast had been recognised and discussed a hundred years ago, and at least one patent bearing on the subject had been taken out. The idea was not therefore novel, but as all previous efforts had been unsuccessful, and had been abandoned, a strong presumption rises that Gayley did actually discover, in connection with his process for removing the moisture, something which had not been known previously. Gayley was the first who fully recognised the significance of the diurnal and even hourly variations of the moisture in the blast, and the first to propose a practical remedy for the resulting evils. He showed that the only way to regularise the conditions is to freeze the moisture, and that no partial measures will meet the case, and the resulting invention is the greatest advance in blast-furnace practice since the introduction of the hot blast by Neilson.

E. S. Cook § also contributes to the discussion of the practical and economic results of Gayley's process.

The development of the Gayley dry air blast is dealt with.||

\* *Bulletin of the American Institute of Mining Engineers*, 1909, pp. 285-290.

† *Journal of the Franklin Institute*, vol. clxviii. pp. 67-74.

‡ *Bulletin of the American Institute of Mining Engineers*, 1909, pp. 81-90.

§ *Ibid.*, pp. 103-106.

|| *Iron and Steel Times*, vol. i. p. 310.

Graphical charts are given \* showing the action of the Gayley dry air blast system in abstracting moisture from atmospheric air. These charts are stated to be the first graphic records of the system that have been published.

**Charging Appliances.**—C. Van Langendonck† gives an account of the overhead railway system installed at the Stumm works, Neunkirchen, Germany, and points out that an overhead railway of this description, with an electrical single drive for the cars, is even more adaptable than wire rope tramways, as the cars can be run automatically. Ore and limestone are delivered from railway trucks into pockets under which the electric railway runs, the materials being drawn off into the overhead trucks by chutes with special gates, and after being run over an automatic weighing machine are taken to the collecting siding where they are separated according to requirements and run to the different parts of the works and furnaces.

O. S. Schmidt‡ calls attention to the extensive use now being made of the overhead railway in ironworks, the facility with which the electrically driven skips can mount comparatively steep inclines rendering the system specially advantageous. Illustrated descriptions are given of the charging arrangements of several blast-furnace plants. In one of these in Milwaukee, the coke and pig iron are put into skips, which are picked up by cranes, weighed while suspended, and placed on trolleys which are then sent up the incline. The advantages of the electric overhead railway for the charging of blast-furnaces are stated to be, its saving of room by running overhead out of the way, the ease with which it is kept in order, and the readiness with which it accommodates itself to almost all localities.

An illustrated description has appeared§ of Aumund's blast-furnace charging machine. With this system it is claimed that the breakage of the coke, and also the faulty distribution of the material in the furnace, are avoided, while at the same time the full advantage of dispensing with the troublesome method of hand-filling is attained.

**Blowing-Engines.**—An illustrated description is given|| of the two-cycle gas blowing-engine plant at the works of the Frodingham Iron and Steel Company. Each engine develops normally 1050 brake-horse-power in one cylinder only. The diameter of the gas cylinder is 35½ inches, the stroke 55½ inches, and the speed 70 revolutions per minute. The blowing cylinder in the case of one of the engines is 71½ inches, whilst the remaining three measure 78¾ inches each.

An illustrated description is given¶ of the gas blowing plant of the Barrow Hæmatite Steel Company.

\* *Iron Trade Review*, vol. xlv. pp. 806, 828.

† *Iron Age*, vol. lxxxiv. pp. 609-610.

‡ *Stahl und Eisen*, vol. xxix. pp. 1377-1384.

§ *Iron and Coal Trades Review*, vol. lxxix. p. 12.

|| *Ibid.*, vol. lxxviii. pp. 685-686. ¶ *Iron and Steel Times*, vol. i. pp. 198-202.



An illustrated description \* has appeared of the gas-power blowing equipment at the works of the Indiana Steel Company, Gary, Indiana. The blowing-house contains eight gas-driven units aggregating in capacity 265,000 cubic feet of free air per minute, and in addition two 45,000 cubic foot steam-driven units. It is contemplated that for each pair of furnaces three gas units will be required, with one spare, the steam units being held entirely in reserve. The 450-ton furnaces each require 44,000 cubic feet of blast per minute. As each blowing unit supplies 33,000 cubic feet of free air per minute the proportion of capacity will be evident. The gas-engines are of the Westinghouse horizontal double-acting type, and work on the four-stroke cycle, with a compression pressure of 200 lbs. at full load.

**Hot-Blast Stoves.**—An illustrated description is given † of a new hot-blast stove designed by A. C. Nelson. The stove has a circular wall surrounding the central combustion chamber, a circular wall close to the shell of the stove and 9-inch square checkers filling the space between these walls.

**Blast-furnace Gases.**—J. B. C. Kershaw ‡ discusses the problem of waste-heat utilisation in ironworks.

**German Blast-furnaces.**—O. Simmersbach § describes, with numerous illustrations, the establishment of the Actiengesellschaft Hochofenwerk, Lübeck, founded with State aid in 1905. Work began on August 8, 1907. Two furnaces are completed, each of which can produce about 175 tons in twenty-four hours; and there are also 100 coke-ovens. For the utilisation of the by-products there are ammonia works and condensation plant, and benzene works are in course of construction. An extensive system of conveyors connects the works with a large wet dock belonging to the company.

A general description of the works of the Oberschlesische Eisenbahn-Bedarfs-Aktien-Gesellschaft at the Friedenshütte is given. || This undertaking from small beginnings has grown into one of the largest metallurgical establishments of Germany. The works now comprise coal and iron mines, blast-furnaces, coke-ovens, steelworks, and rolling-mills, with the subsidiary industries in connection with these different branches. The different processes of steel manufacture are described in considerable detail.

**Russian Blast-furnaces.**—Z. Bielski ¶ gives an account of the establishment and development of the several ironworks in South Russia, and describes their blast-furnace plant and steelworks equipment.

\* *American Machinist*, vol. xxxii. Part I. pp. 723-727.

† *Iron Age*, vol. lxxxiv. pp. 194-195.

‡ *Iron and Coal Trades Review*, vol. lxxviii. p. 501.

§ *Stahl und Eisen*, vol. xxix. pp. 611-620.

¶ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lvii. pp. 479-483, 491-495. || *Ibid.*, pp. 929-945.

**Blast-furnaces in India.**—The blast-furnace plant of the Tata Iron and Steel Company, Bombay, is described.\*

**Canadian Blast-furnaces.**—G. C. Mackenzie † gives a description of the various ironworks in the province of Ontario.

**American Blast-furnaces.**—In an account of the chief plants operating in the Birmingham, Alabama, district, J. L. Pultz ‡ describes the principal blast-furnace installations and the general condition of the iron trade. In the Birmingham district proper there are twenty-seven furnaces with a combined annual capacity of over 2,000,000 tons, although owing to general industrial depression this maximum has not been reached for the last two or three years.

**Charcoal Blast-furnaces.**—M. A. Pavloff § describes the charcoal blast-furnace practice in the Urals, with diagrams of the furnaces and detailed analyses of the ores and pig iron produced. Owing to want of capital the Ural furnaces are not always properly equipped and the blast is sometimes deficient in volume and of too low temperature; but the average daily output per furnace is 22·5 English tons as against 16·5 tons per charcoal furnace in Sweden. The ores treated vary enormously in composition, the best being the Baikal iron ores smelted at the Ermolovskaia furnace, South Ural. Here the average daily output is 54 tons, and it would be much higher had not the mistake been made of erecting iron pipe stoves instead of regenerative stoves. The other furnaces described are those of Klimkovskaia, Nadejdinsky, Nijni-Saldinsky, and Blagodat; a map of the district is given, and a table summarising the conditions and results of charcoal blast-furnace practice in Russia, Sweden, and America.

An illustrated description of the Jefferson furnace of the Jefferson Iron Company, Oak Hill, Ohio, has appeared. || It is a typical Hanging Rock charcoal furnace dating back to 1854. Only three or four of these furnaces have survived the cutting away of the forests which at one time provided ample and convenient supplies of charcoal, and the next few years will inevitably witness the end of their operations. In some respects, however, the Jefferson furnace is unique, as, with a capitalisation of only \$34,500, the company was in fifteen years able to declare dividends aggregating over \$400,000; and equally unique was its custom of always suspending operations on Sundays. The surrounding hills were covered with a heavy growth of timber suitable for charcoal, of which, with cold blast, from 175 to 200 bushels were required per ton of pig iron produced. The ores were similarly obtained from adjacent hills, and sometimes ran as high as

\* *Iron and Coal Trades Review*, vol. lxxix. p. 464.

† *Annual Report of the Bureau of Mines*, Toronto, vol. xvii. pp. 290-326.

‡ *Engineering and Mining Journal*, vol. lxxxviii. pp. 345-348.

§ *Engineer*, vol. cvii. pp. 493-496.

|| *Iron Trade Review*, vol. xlv. pp. 251-254.

60 per cent. of iron; while ample limestone supplies were also found in the vicinity. The output of the furnace was never more than 13 tons per day, and averaged about 10 tons. From an inspection of the old books, from which extracts are given, it will be found that although prices were often very low, supplies and labour were cheap. Towards the end of the Civil War, however, prices improved, and from \$85 to \$100 could be obtained per ton of iron. Much of the iron was used for the manufacture of large guns during the war.

**Electro-smelting of Iron.**—E. Haanel\* has described in detail the electric furnaces at Domnarfvet, Sweden, intended for the production of pig iron, and the process employed. The actual furnace was illustrated in a paper by E. J. Ljungberg, read at the autumn meeting of the Iron and Steel Institute in London, and published in the present volume;† but further details as to its construction and mode of working, together with a description of the previous experimental work which led to its adoption, are now given. The construction of the preliminary furnace was commenced in April 1906; and towards the end of that year the furnace was put in operation. From that time experiments were continuously carried on and improvements made; the daily experience thus gained being utilised in successive changes in design and reconstruction towards perfection.

With a view to elucidating a number of disputed technical points involved in the smelting process itself, initial experiments were conducted at Ludvika during the summer of 1907, with a small furnace of 300 horse-power capacity. During these preliminary experiments many difficulties were encountered which had to be overcome; and it was not until the summer of 1908 that a furnace which could be economically used in practice was designed. Towards the end of the summer a number of experiments were made with this furnace, which demonstrated that the type evolved was durable, and that a good output could be obtained therefrom, notwithstanding the fact that the furnace was constructed with a relatively low shaft in order to reduce the building expense. The new furnace was completed early in December 1908.

The experimental plant was installed in an old building adjoining the basic-Bessemer converter house. The machinery consisted of a three-phase synchronous motor of about 900 horse-power, supplied with a current of 7000 volts, and 60 periods, from a three-phase cable line in the ironworks. The motor was directly coupled to a three-phase generator, which supplied current of 25 periods, adjustable to between 300 and 1200 volts, through small intervals to the transformers erected in the immediate vicinity of the furnace. By regulating the tension of the generator, the low tension sides of the transformers can be altered, through small intervals, from 20 to 85 volts. The ratio of transformation can be altered to 7: 1 by means of

\* *Canada, Department of Mines, Ottawa, 1909.*

† pp. 9-14 *ante*.

certain easily performed changes of coupling in the transformers; in which case the low tension can be varied between 40 and 170 volts. The transformers are cooled with air supplied under pressure by two electric blowers. A switchboard is situated conveniently near the furnace for controlling its operation.

In general appearance the electric shaft furnace itself is unlike any hitherto constructed, being very similar in design to an ordinary blast-furnace in which the tuyeres are replaced by electrodes. The height of the furnace above ground level is about 25 feet. The melting chamber or crucible containing the electrodes is about 7 feet high, and is of greater diameter than any other part. The shaft is about 18 feet high, the lower end of which—for about 4 feet—has the form of a truncated cone, for the purpose of directing the charge into the crucible in such a manner that the electrodes, lining, and descending charge could not come in contact. This special feature in the design was introduced by the inventors after repeated experiments which demonstrated that the upper surface of the column formed by the materials charged into the furnace assumes a definite angle: viz.,  $50^{\circ}$  to  $55^{\circ}$  to the vertical, when the materials—crushed to normal size, and at the same temperature as that existing in the melting chamber—are allowed to fall through a circular aperture into a free space.

It is this isolation of the descending charge from the lining at the point where the electrode enters the furnace that constitutes the particular economic advantage of the construction, since it prevents the destruction of the lining which occurred in all previous furnaces where the electrode came directly in contact with the melting charge and the lining, for the temperature of the brickwork in close proximity to the electrodes becomes so great that the most refractory lining materials are rapidly destroyed—even when the electrodes are cooled by water-jackets. The contracted neck of the shaft immediately over the central opening into the melting chamber is not supported by the arched roof, but the entire weight of the shaft is carried by six cast-iron columns arranged symmetrically around the furnace hearth. The melting chamber is made in the form of a crucible, and is covered with an arched roof provided with openings for the reception of the electrodes and the descending charge. The roof and walls of the crucible are lined with magnesite.

For the purpose of cooling the brickwork composing the lining of the roof of the melting chamber, and thereby increasing its life, three tuyeres are introduced into the crucible—just above the melting zone—through which the comparatively cool, tunnel-head gases are forced against the lining of the roof into the free spaces. This gas absorbs heat from the exposed lining of the roof and walls, and the free surface of the spreading charge, thus effectively lowering the temperature of the roof and exposed walls. With the exception, however, of radiation from the tuyeres, no heat is lost by this method of cooling, or lowering of temperature.

The iron ore placed at the disposal of the inventors for the trial

run was magnetite from Grängesberg, and had the following composition :—

	Per Cent.
Magnetic oxide . . . . .	66·46
Iron peroxide . . . . .	21·21
Manganese oxide . . . . .	0·30
Magnesia . . . . .	0·98
Lime . . . . .	3·84
Alumina . . . . .	1·07
Silica . . . . .	3·16
Phosphoric acid . . . . .	2·34
Sulphur . . . . .	undetermined
Total iron . . . . .	62·96

During the first part of the trial run, coke containing 85 per cent. carbon and 0·55 per cent. sulphur was used. This, however, had been exposed for a long time to the open air and rain, which made its percentage of moisture unusually high. Lime was used as a flux.

The raw material—crushed to pieces of about 1 inch diameter—was conveyed to the charging floor of the furnace, where it was weighed, and charged by hand. The instruments were read every half hour, the product of each tapping carefully weighed, and samples of both the iron and slag taken for analysis. The iron and slag were tapped through the same hole; but no difficulty was encountered in separating the iron from the slag after cooling. The men operating the furnace were divided into two shifts, each shift being of twelve hours' duration, and consisting of four labourers and a foreman.

Although the furnace was designed for a much larger capacity, the power available at this time was only 400 to 450 kilowatts. The pressure was kept at between 40 and 50 volts, and the power factor—which, with the lower voltage during the first part of the run, was 0·85—rose to 0·90 with the higher voltage.

Details are given of the trial run, showing the power consumption and the nature and composition of the pig iron produced. The trial run was intended to elucidate the following points :—

(1) Whether undisturbed and uniform working without troublesome regulation of the electrodes could be obtained.

(2) Whether great variations in the consumption of energy would occur.

(3) Whether the free spaces within the melting chamber would be maintained with a shaft considerably higher than in the furnaces of earlier design and construction.

(4) Whether the contraction of the shaft would prevent the charge from sinking uniformly, or cause hanging.

(5) The durability of the arched roof, and the possibility of cooling it by means of the circulating gas.

The following is a summarised statement of practical deductions drawn from observations made during the trial run having regard to the objective points specified above :—

(a) It was observed that the furnace operated uniformly and without trouble of any kind, and that the electrodes required absolutely

no regulation, in one case, for five consecutive days. In any case, the only regulation required is that corresponding to the consumption of the electrodes, and is necessary only once a day, and sometimes not for much longer periods. On account of this, expensive regulating appliances can be dispensed with.

(b) During the short trial, even though the furnace did not approach its normal working condition until towards the end, it was observed that the consumption of energy was remarkably uniform. This can readily be seen from an inspection of the readings of the different instruments.

(c) Free spaces were maintained between the linings of the roof and walls, and the electrodes and charge at the openings where the electrodes enter the melting chamber.

(d) It was found that the charge did not jam in the lower contracted neck of the shaft, as had been feared, but moved with regularity into the melting chamber.

(e) Although the gases generated by the reduction of the ore were not circulated through the cooling tuyeres until near the end of the trial run, it was demonstrated that the lining of the roof of the melting chamber was effectively cooled by this means.

The following comparison of the cost of production of pig iron in the charcoal blast-furnace with that produced in the electric shaft furnace was prepared by E. G. Odelstierna \* as an addendum to the foregoing. In this comparison no account is taken of the fact that the gases produced in the electric shaft furnace contain a higher percentage of carbon monoxide—probably 60 per cent. more—than the ordinary blast-furnace gases. The labour charges and general expenses are assumed to be the same for both the electric shaft furnace and the charcoal blast-furnace, if the contrasted furnaces are of such capacity as to produce the same quantity of pig iron per year. A charcoal blast-furnace of medium capacity produces in Sweden about 8000 to 10,000 short tons of pig iron per annum.

*Cost of Pig Iron per Short Ton in Dollars.*

<i>Charcoal Blast-furnace.</i>		<i>Electric Shaft Furnace.</i>	
Charcoal, 0.95 ton at \$8 per ton .	\$7 60	0.27 ton . . .	\$2 16
Electrical energy . . . . .	0 00	0.3 E.H.P. year at \$12 . . .	3 60
Labour . . . . .	1 00	10 lbs at 3c. per lb. . . . .	1 00
Electrodes . . . . .	0 00	. . . . .	0 30
Repairs and general expenses .	1 50	. . . . .	1 50
	<u>\$10 10</u>		<u>\$8 56</u>

In this calculation the price of ore and limestone and the royalty are not given, as the former varies with the locality and the character of the ore, and the latter has not yet been determined. From this calculation it is apparent that in Sweden, under the above-mentioned circumstances, a saving of \$1.55 per ton should be effected in the production of pig iron by the electro-thermic process.

\* Canada, Department of Mines, Ottawa, 1909.

The results are given \* of a series of tests made in the smelting of Tuollavaara ore, in the electric furnace now in operation at the Domnarfvet works, Sweden. The ore showed the following analysis :—

	Per Cent.
Peroxide of iron . . . . .	1·9
Iron oxides . . . . .	93·5
Manganous oxide . . . . .	0·1
Lime . . . . .	0·6
Alumina . . . . .	2·0
Silica . . . . .	1·8
Iron . . . . .	68·9

The total time occupied was 219 hours. During this time the current was turned off for 16 hours on account of defects in the machinery, and changing of an electrode, leaving an actual smelting time of 203 hours. The charges were as follows :—

Tuollavaara Ore.	Coke.	Charcoal.	Limestone.	Number of Charges.
Kilogrammes.	Kilogrammes.	Kilogrammes.	Kilogrammes.	
100	11	11	4	149
100	12	11	4	181
100	8	15	4	156
100	8	17	4	56
100	7	17	4	75
Total number of charges . . . . .				617

The material used was—ore, 61·7 metric tons; limestone, 2468 metric tons; coke, 6·032 metric tons; charcoal, 8·197 metric tons. The electrical energy required amounted to 112,109 kilowatt-hours, or 17 horse-power-years. The output of pig iron was 43·5 metric tons, with a carbon percentage varying from 2·33 to 3·09. Per ton of pig iron there was used: Electric energy, 0·39 horse-power-years; coke, 0·139 metric ton; total coal, 0·327 metric ton; charcoal, 0·188 metric ton. The coal used was of rather poor quality, the tests showing percentages of carbon from 0·65 to 0·75 in the charcoal, and 0·8 in the coke.

The pig iron smelted per horse-power-year was 2·56 metric tons; and the production in twenty-four hours, 5·15 metric tons. The total amount of slag was about 7000 kilogrammes, containing from 1·59 to 4·25 per cent. of iron. The average of the analysis made showed 2·95 per cent. The amount of iron in the slag thus was about  $00·295 \times 7000 = 206·5$  kilogrammes, or 0·47 per cent. of iron produced. The consumption of electrodes has been judged from the two electrodes last exchanged, which had been in twenty-two and thirty days respectively. It was 9 kilogrammes per ton of pig iron.

\* *Iron and Coal Trades Review*, vol. lxxix. p. 173.

A company has been formed for the purpose of establishing electric ironworks at the Trollhättan Falls in Sweden. The plant is to comprise three electric furnaces, each of 2500 horse-power, with a capacity of 7500 tons of pig iron per year. The Waterfall Board has agreed to charge the company £1, 10s. 8d. per horse-power-year for the first ten years, and £2, 0s. 11d. for the next ten years. Suitable iron ore can be obtained from several places along the Bergslagens Railway, or at some port on Lake Väuern, which has waterway connection with Trollhättan. According to the calculations, pig iron can be produced at £2, 16s. 8d. per ton. A considerable increase of power can be obtained, and there is no lack of ore, so the possibilities of extension are everything that can be desired.\*

It is reported † that the Aktiebolaget Elektrometall, of Ludvika, Sweden, will erect in Norway what will be one of the first electric smelting plant in the world on a commercial scale for the production of pig iron. The first installation will be built this summer, and will include two iron-ore reduction furnaces of 2500 horse-power each, and two steel furnaces of 600 horse-power each. All furnaces will be operated with two-phase current. The plant will later be enlarged by erecting four more iron-ore reduction furnaces of 2500 horse-power each, and four steel furnaces of larger size than 600 horse-power. Besides the electric smelting and refining plant, the installation will include a rolling-mill.

F. C. Perkins ‡ gives an account of the working of an experimental 160 kilowatt Lyon-Clevenger single-phase furnace for smelting iron ore, installed by the Noble Electric Steel Company at Héroult, Shasta County, California. The furnace consists of a concrete stack 29 feet high, with electrodes fixed in the walls of the crucible, the charging being done from the top, so that a long column of the charge is pre-heated before reaching the zone of fusion between the electrodes. The electrodes are 24 inches apart, and the crucible is lined with firebrick, and is water-cooled. The cost of electrical energy, generated by water-power, is \$16 per kilowatt-year, and as an average of 1 to 1½ tons of iron were produced per day, at a cost of 0.262 kilowatt-year per ton, this represents \$4.20 for electric energy per ton of pig iron. With a larger furnace the prospects are even better. A new furnace of 1500 kilowatts is being constructed by the company in which it is expected to produce from 15 to 20 tons of pig iron per day, with an expenditure of 0.25 kilowatt-year per ton or less, or about \$4 per ton for electrical energy.

F. Louvrier § discusses the merits of electric furnaces as compared with fuel furnaces, and, in addition to certain other economies, claims the following advantages obtained by the use of electricity as a source of heat: (1) Great facility in the regulation of the heat by the simple handling of the electrodes. (2) Constant production of the

\* *Engineering*, vol. lxxxvii. p. 829.

† *Electrochemical and Metallurgical Industry*, vol. vii. p. 146.

‡ *Mining World*, vol. xxx. p. 535.

§ *Electrochemical and Metallurgical Industry*, vol. vii. pp. 159-162.



exact temperature necessary, no matter how high. (3) Entire elimination of the chilling of the slags, so prejudicial in coke furnaces. (4) Easy treatment of all classes of ores, no matter how refractory. (5) Higher percentage in recovery of metals as a consequence of (a) the non-oxidising action of the electric heat, which is produced without air or oxygen; (b) the production of less slags, of greater fluidity. (6) Decrease in manual labour (a) due to less quantity of materials to be handled; (b) because the ores can be treated as they come from the mines, without the necessity of having them broken, or bound when in dust. (7) Complete suppression of blowers and tuyeres. (8) Decreases in expenses of maintenance and repairs due to the maximum temperature being in the centre of the ores treated, and not on the walls of the furnace, as in ordinary furnaces. (9) Production of a purer product, electrical energy being chemically neutral, and not conveying to the metal the impurities always contained in the usual fuels. (10) Possibility of operating profitably mines situated far from means of communication, due to facility of transmission of the electrical energy. (11) In all cases, decreases in transportation expenses, due to the facility of treating the ores even at the mines. (12) Yields as high in ratio from smaller plants as from larger plants. Some of these advantages would, of course, be affected by the relative costs of electricity and the usual fuels.

R. Catani,\* in dealing with electric iron and steel furnaces, states that if the electric furnace is to compete with other processes for iron and steel production, it must be of large capacity. Single-phase *versus* polyphase current for large electric furnaces is also discussed, and the advantages and disadvantages of the three-phase as compared with the single-phase furnace are specified.

C. A. Hansen † describes the results of an extended investigation of the losses due to the electrodes in an electric furnace. Comparison is made between amorphous carbon and artificial-graphite electrodes, and many diagrams showing the variations of various physical properties of carbon and graphite with temperature are given.

J. W. Richards ‡ reviews the conditions under which the reduction of iron ore may be rendered practicable in an electrically heated furnace.

**History of Iron.**—F. W. Harbord § reviews the various causes which have assisted in the vast developments in the iron and steel industry during the last hundred years.

G. Turner || continues his description of the iron industry of England.

The history and development of the Shropshire metallurgical

\* Paper read before the American Electrochemical Society, May 6-8, 1909; *Electrochemical and Metallurgical Industry*, vol. vii. pp. 268-269.

† *Ibid.*, p. 270.

‡ *Ibid.*, 253-254.

§ *Journal of the Society of Chemical Industry*, vol. xxviii. pp. 867-873.

|| *Ironmonger*, vol. cxxviii. pp. 226-227.

industry, together with that of the Coalbrookdale Company, are traced.\*

Illustrations have appeared † of the charcoal-iron furnace at Duddon Bridge, Cumberland, which was started in 1740, but ceased operations in 1870, also of the furnace at Backbarrow, Furness, started in 1710, and at the present time the only charcoal furnace in the British Isles.

A. Vicaire ‡ deals with the development of the metallurgical industry in the Loire basin.

G. Goldstein § traces the development of the German pig-iron industry from the year 1879.

An interesting description of the early methods of manufacture of iron in Sweden is given by A. F. Backlin. †

The development of the iron and steel industry in India is dealt with. ¶

The early history of ironmaking in Ontario is dealt with by G. C. Mackenzie. \*\*

H. E. Birkinbine †† gives an account of the extinct iron industry of Southern Illinois, where, half a century ago, two charcoal blast-furnaces existed in Hardin County, for the purpose of smelting the native iron ores with charcoal as fuel. Extensive forests existed at that time, but the timber now prevailing in the region is of second growth.

Thomas Turner †† (Birmingham) gives a brief outline of the state of the knowledge of cast iron twenty-five years ago (1884), and presents a summary of the work that has been carried out upon cast iron at the University of Birmingham from that time up to the present.

In connection with a biographical notice of the late Henry Montagu Hingley, an historical account is given §§ of the rise and development of the chain-making industry of Staffordshire, with which the firm of N. Hingley & Son has for a century been prominently associated.

O. Vogel ||| gives a review of the rise and progress of the tin-plate industry in Germany from the earliest period of which any record exists — namely, about the middle of the fifteenth century. Originating in Bavaria, the industry spread to Saxony and Upper Silesia, but collapsed entirely under the competition of the superior English plate in the seventeenth and eighteenth centuries; and

\* *Iron and Steel Times*, vol. i. pp. 293-300.

† *Ibid.*, p. 339.

‡ *Bulletin de la Société de l'Industrie Minière*, vol. x. pp. 31-73.

§ *Verhandlungen des Vereines zur Beförderung des Gewerbfleisses*, 1908, pp. 175-214, 307-322, 415-430, 475-490, 528-550.

¶ *American Wire Rope News; Iron Trade Review*, vol. xlv. pp. 1031-1033.

¶¶ *Iron and Coal Trades Review*, vol. lxxviii. p. 577.

\*\* *Annual Report of the Bureau of Mines*, Toronto, vol. xvii. pp. 190-201.

†† *Iron Trade Review*, vol. xlv. pp. 247-249.

‡‡ Paper read before the British Foundrymen's Association; *Foundry Trade Journal*, vol. xi. pp. 532-538.

§§ *Iron and Steel Trades Journal*, vol. lxxxv. p. 477.

||| *Stahl und Eisen*, vol. xxix. pp. 1097-1107.

at present the production of tinplate is mainly confined to the works at Rasselstein, Dillingen, Hayingen, Hüsten, and Nachrodt. With regard to the present output and trade in tinplate of the chief commercial nations, the following summary may be given: In Germany the production has increased from 21,348 tons in 1890 to 48,334 tons in 1908. Austria has only four tinplate works—namely, at Wasendorf (Styria), Wöllersdorf (Lower Austria), and Neudeck and Rothau (Bohemia). These have a working understanding, and the total output is only some 8800 tons per annum. The only producing works in Hungary are at Nádaszt. In France tinplate is made at Montataire, Hennebont, Châtillon-Commentry, Bourg (Franche Comté), and a few other places. The total output is uncertain, in the absence of statistics. Belgium does not appear to be producing tinplate at all. In Italy the tinplate industry is of comparatively recent origin, but the production has grown from 2918 tons in 1896 to 24,423 tons in 1907. The works are situated at Piombino, Savona, and Darfo. The Spanish industry is also growing, the production having increased from 12,992 tons in 1903 to 16,842 tons in 1908. Russia has now several tinplate works, and a number of preserve manufacturers have their own tinning plant. No statistics of the output are available. The quality of Russian plate is reported to be inferior. Sweden no longer produces tinplate, although the quality of Swedish iron is suitable for the purpose. The output of English tinplate increased considerably between 1865 and 1891, the figures for these years being, respectively, 70,400 tons and 673,600 tons, and, after a set-back for several years, resumed an upward course, the output for 1908 being about 700,000 tons. The greatest development in the tinplate trade is exhibited by the United States, for while in the last six months of 1891 the output was only 1016 tons, it had grown to 366,995 tons in 1899, the maximum, 587,358 tons, being reached in 1906, since which date it has receded, having been only 482,600 tons in 1908. At present the industry consumes nearly 1½ million tons of iron ore, 850,000 tons of coke, and 400,000 tons of limestone.

In considering, historically and statistically, the history of the manufacture of tin and terne plates, W. G. Gray\* states that the manufacture of tinplates originated in Bohemia, hammered iron plates having been coated with tin in that country some time before the year 1600. Tinplate making was introduced into England in 1665, the art being brought there from Saxony. In France the first tinplate factory was established in 1714. The first commercial manufacture of tinplates in the United States was at Pittsburg in 1872; but the industry did not develop largely until after 1890.

Biographies and portraits of individuals prominently connected with the iron and steel industries have been published in the *Ironmonger* (vol. cxxvii. p. 167) of W. E. Allen; in *Engineering* (vol.

\* Paper read before the Philadelphia Master Tin and Sheet Metal Workers' Association, April 14, 1909; *Iron Age*, vol. lxxxiii. pp. 1598-1601.

lxxxvii. p. 859) of T. E. Vickers; in the *Iron and Coal Trades Review* (vol. lxxix. p. 13) of S. J. P. Thearle and H. J. Cornish.

## II.—CHEMICAL COMPOSITION OF PIG IRON.

**Pig-iron Analyses.**—As a supplement to tables previously published,\* a series of analyses of pig irons produced by British makers is given,† together with tables showing typical analyses of irons produced in the different districts.

J. A. Leffler ‡ discusses the composition of various classes of foundry iron, and gives analyses of these.

**Classification of Foundry Iron.**—M. Orthey§ has made researches on the distribution of impurities in pig iron. The results proved that different pigs of the same tapping were not of regular composition throughout, and the variations were considerable. In almost all cases the variations of the percentages of silicon, manganese, and sulphur were considerable. A table is appended giving the results of the analyses. The pigs, when broken and charged in a cupola, undergo sufficient mixing, and the resulting iron is practically regular in composition.

A. H. Hiorns|| deals with the influence of chemical compounds on the properties of foundry iron, and considers in detail the parts played by carbon, silicon, phosphorus, sulphur, and manganese, and the various compounds of those elements in determining the qualities of cast iron.

## III.—BLAST-FURNACE SLAGS.

**Slag Cement.**—M. Lepersonne¶ describes various processes for the manufacture of cement from blast-furnace slags, including the Passow, Grau, Wolff and Lessing, and Mathésius processes. The theory of the subject is dealt with, and the influence of the addition and admixture of extraneous matters to the product discussed.

H. Passow\*\* proposes a series of tests to show which of the two disputing parties, Colloseus and Passow, is right in the claim concerning the value or non-value of the Colloseus process. The slag is to be taken from three different blast-furnaces, and each of these

\* *Foundry Trade Journal*, vol. x. pp. 49-50.

† *Ibid.*, vol. xi. pp. 474-477.

‡ *Eisen Zeitung*, vol. xxx. pp. 381-383, 403-505.

§ *Giesserei Zeitung*, vol. vi. pp. 257-259, *et seq.*

|| Paper read before the British Foundrymen's Association, August 4, 1909.

¶ *Revue Universelle des Mines*, vol. xxv. pp. 274-290.

\*\* *Metallurgie*, vol. vi. pp. 167-168.

slags is to be granulated in the ordinary way with water—by the Passow method with ordinary water, and by the Colloseus method with an alkaline solution. The slags so prepared should be ground each with similar additions of lime compounds, and tested in a properly equipped laboratory.

H. Kühl,\* in discussing the Colloseus process, observes that according to Passow's theory of the hydraulic properties of blast-furnace slag, all attempts at improving the methods of manufacture of cement from slag are useless. For, according to Passow, the only factor which influences the properties of the slag during cooling is the rate at which it cools. This theory, however, takes no account of the part played by the sulphate of lime. The assertion that treatment with an alkaline solution is necessary for the hardening of the vitreous modification of the slag is incorrect. Potassium hydrate, for instance, does not produce the same effect as calcium hydrate. The moderately cooled slag must contain substances of different chemical character, and the retention or formation of as many hydraulic constituents as possible should be aimed at. The Colloseus process, which consists of treatment with salt solutions, may give reactions and results different from those obtained by cooling in water in the ordinary way.

Colloseus† discusses the criticism of Passow‡ on the paper on slag cement read by C. von Schwarz§ before the Iron and Steel Institute.

W. M. Kinney|| describes the manufacture of Portland cement from blast-furnace slag.

At the cement works of the Coltness Iron and Coal Company at Newmains, Lanarkshire, a Bleichert aerial ropeway has been installed. Iron buckets with a capacity of 1 ton convey the granulated slag from the furnaces to the clinker house. The cement is the product of the waste slag, and is equal to the best quality of Portland cement.¶

\* *Tonindustrie Zeitung*, vol. xxxii. pp. 2046-2049.

† *Metallurgie*, vol. vi. pp. 20-21.

‡ *Ibid.*, vol. v. pp. 410-412.

§ *Journal of the Iron and Steel Institute*, 1908, No. I. p. 137.

|| *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xxv. pp. 103-138.

¶ *Colliery Guardian*, vol. xcvi. p. 882.

## FOUNDRY PRACTICE.

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**Cupola Practice.**—A. Messerschmidt\* describes practice in cupola construction, melting processes, and methods of charging cupolas.

A very large cupola in the foundry of the Standard Cast Iron and Foundry Pipe Company, Bristol, Pennsylvania, is described and illustrated.† The internal diameter of the furnace is 108 inches, and the outside diameter is 130 inches, the capacity being from 27 to 30 tons per hour. The tuyeres are arranged in two rows of eight, placed one above the other.

An illustration is given ‡ of a Whiting cupola, the diameter of the shell of which is 27 inches, and the total over-all height 10 feet. The cupola is mounted on trunnions, through which the blast-pipe is carried, and has been specially designed for test purposes. It is also suitable for technical schools and as a general portable cupola for emergency or repair work.

S. D. Sleeth§ describes the system of continuous melting in the foundry of the Westinghouse Air Brake Company, Wilmerding, Pennsylvania. This consists in running the cupola all day and pouring the castings at frequent intervals, instead of leaving it to the latter part of the afternoon.

R. H. Probert|| also gives particulars of the method of continuous melting in the foundry of the Dow Iron and Wire Works, Louisville, Kentucky, describing how the charge is made up.

W. J. May¶ describes a method of continuous melting with the ordinary cupola.

C. R. McGahey\*\* deals with the use of steel scrap in the cupola, and gives the results of tests on bars that had been made with the addition of steel scrap.

J. C. Knoeppel,†† in dealing with modern cupola practice, gives suggestions as to the proper management of the cupola. He describes

\* *Stahl und Eisen*, vol. xxix. pp. 1182-1190, 1384-1391, 1558-1562, 1730-1738, *et seq.*

† *Giesserei Zeitung*, vol. vi. p. 149.

‡ *Foundry Trade Journal*, vol. xi. p. 496.

§ *Transactions of the American Foundrymen's Association*, vol. xxviii. pp. 13-15.

|| *Ibid.*, pp. 47-53.

¶ *Foundry Trade Journal*, vol. xi. pp. 472-473.

\*\* *Transactions of the American Foundrymen's Association*, vol. xxviii. pp. 113-116.

†† *Ibid.*, pp. 73-79.

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a system of tuyeres especially intended to effect the introduction of the blast at as low a pressure as possible, so as to insure a low melting point with its attendant advantages.

J. W. Henderson \* deals with the economy in cupola melting.

O. Binder † discusses the chemical reactions in the cupola.

M. Albutz ‡ deals with the chemical action and influence of fluxes in cupola melting.

**Composition of Cupola Gases.**—G. Buzek,§ after premising that only the carbon monoxide in the gases of cupolas is as a rule analytically determined, discusses the effect of the oxygen and nitrogen which are also present. He gives a table showing the calculated quantities of cupola gases with different combustion-ratios of carbon dioxide to carbon monoxide and to varying amounts of excess of air and oxygen.

**Foundry Mixtures.**—A new method of treating pig iron in the foundry is described.|| The process consists of the addition of a special flux and certain proportions of other metals to the iron, either in the ladle or the cupola. It is claimed that by the addition of the flux only to common pig iron a clean, crisp casting, with a close grain, is obtained, whilst the tensile strength is said to be from 20 to 30 per cent. above that of the same iron unfluxed, the crushing strain and the elastic limit being equally satisfactory. By the addition of nickel and flux to ordinary pig iron, castings can be made in open sand without requiring any subsequent treatment.

**Chemistry in the Foundry.**—In dealing with the practical value of chemical standards for iron castings, J. J. Porter¶ states that the quality of a casting depends upon the chemical composition, the treatment which the metal receives in melting, the heat treatment, and the perfection of the mould. The author considers that the reason the present knowledge of foundry metallurgy is not more generally applied is that the various data have not been placed together in such form as to be of assistance to practical foundrymen, and suggests that, in order to present these metallurgical data in such a form as to make it of practical value, castings should first be classified according to their important physical properties, and then that the chemical compositions which are found suitable for each class should be tabulated. He further suggests that an investigation carried out on these lines would be of immediate and direct benefit to the foundry industry.

\* *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xxv. pp. 313-332.

† *Eisen Zeitung*, vol. xxx. pp. 553-554, 573-574.

‡ *Foundry Trade Journal*, vol. x<sup>2</sup>. pp. 492-493.

§ *Stahl und Eisen*, vol. xxix. pp. 712-714.

|| *Foundry Trade Journal*, vol. xi. p. 300.

¶ *Transactions of the American Foundrymen's Association*, vol. xxviii. pp. 17-22.

**Foundry Specifications.**—The revised recommendations of the American Foundrymen's Association's Committee on Standard Specifications for Foundry Iron have been published.\*

**British Foundry.**—An illustrated description is given † of the foundry at the Edgwick Works, Coventry.

**German Foundries.**—O. S. Schmidt ‡ describes modern appliances for the transport of material and for cupola charging in German foundries. At the Thyssen and Phoenix works the Bleichert electric overhead railway system has been adopted. In the first of these a double track traverses the stockyard at such a height that the materials for charging can conveniently be discharged from the railway trucks into skips of 1 ton capacity suspended from the single overhead rail, the required proportions of pig iron, limestone, and coke being put into each skip together. Each skip is provided with a weighing apparatus to enable the proper quantities to be apportioned. The quantities are noted on the skips and controlled at the cupola. They run horizontally at a speed of 60 metres per minute into a lift, in which they are raised to the height of the charging platform, and they then make their way onward at a reduced speed into large bins beside the cupolas, whence their load is shot into the latter. An additional track is laid, which can be used in case of breakdowns.

**Swiss Foundry.**—The foundries of Sulzer Brothers, of Winterthur, are described. The foundry works, which cover an area of about 34,000 square yards, and give employment to 1400 workmen, are among the largest in Europe.§

**Canadian Foundry.**—An illustrated description is given || of the equipment of the Enterprise Foundry Company, Sackville, New Brunswick.

**American Foundries.**—A fully illustrated description has appeared ¶ of the machine shops and foundries of the Mesta Machine Company, West Homestead, Allegheny County, Pennsylvania. The foundry equipment is on a large scale, and the air furnaces employed have a total capacity for melting 250 tons of iron at one heat, if required. The steel foundry contains acid open-hearth furnaces capable of making 125 tons of castings per day.

A description is given \*\* of the foundry of the Indiana Steel Company at Gary. The building measures 137 feet by 400 feet, and

\* *Transactions of the American Foundrymen's Association*, vol. xxviii. pp. 236-257.

† *Iron and Coal Trades Review*, vol. lxxix. p. 312.

‡ *Stahl und Eisen*, vol. xxix. pp. 1377-1384.

§ *Ibid.*, pp. 1009-1021.

|| *Canadian Machinery*, May 1909, pp. 62-64.

¶ *Iron Age*, vol. lxxxiv. pp. 465-471.

\*\* *Ibid.*, vol. lxxxiii. pp. 1407-1411.



the moulding floor occupies the entire middle bay, 61 feet in width. In the iron foundry there are installed one 72-inch and one 46-inch cupola to which blast is delivered by two blowers electrically driven. There is also a 750-lb. Schwartz furnace for aluminium and brass castings. At the western end of the iron foundry there is a 25-ton acid open-hearth steel furnace for the manufacture of steel castings.

An illustrated description has appeared \* of the new foundry of the General Electric Company, Pittsfield, Massachusetts. The foundry proper is 360 feet long and 150 feet wide. Two Whiting cupolas are in blast alternately, and produce from 5 to 7½ tons per hour. Eighteen pairs of Pridmore moulding machines and 10 hydraulic pressure moulding machines are installed.

**Foundry Patterns and Moulding.**—T. Löhe † discusses methods of moulding. A simple rope-pulley of three different sizes, 12, 24, and 48 inches diameter, is taken as an example. With the smallest size a divided pattern with groove is preferable, because the flasks can be readily turned over. For the medium pulley an undivided pattern with core prints and core boxes is the most simple. The high cost of a pattern for the large pulley can be avoided by templet-moulding.

F. R. Cheney ‡ discusses cores and binders, and gives suggestions for core-making.

W. H. Sherburn § deals with the production of patterns for light castings.

R. A. Bull, || in discussing the contentions of E. F. Lake ¶ with reference to green sand moulding, gives the results of his determinations concerning the specific gravity of cast steel, and states that definite conclusions were reached as to the relative homogeneity of steel cast in dry and green sand moulds. It is shown that cast steel poured in sun-dried moulds has 1·7 per cent. less density than steel poured in baked moulds, and that steel cast in entirely green sand moulds has its specific gravity lowered only slightly below that found common to steel poured in thoroughly dried moulds.

A description is published \*\* of a new automatic apparatus for the preparation of moulding sand for foundries.

H. F. Frohman, †† in dealing with the standardisation of foundry facings, states that it has been found that plumbago or graphite of a high graphitic carbon is the best material for the purpose of facing, not only in dry sand, but in green sand work, and also for blacking cores. Approximate chemical analyses of typical Ceylon graphite, coke blacking, anthracite blacking, and charcoal facing, are given.

\* *Giesserei Zeitung*, vol. vi. pp. 266-273.

† *Ibid.*, pp. 261-264 et seq.

‡ *Transactions of the American Foundrymen's Association*, vol. xxviii. pp. 1-4.

§ Paper read before the British Foundrymen's Association, August 3, 1909.

|| *American Machinist*, vol. xxxii. Part I. p. 626.

¶ *Ibid.*, p. 168.

\*\* *Engineering*, vol. lxxxvii. p. 486.

†† *Transactions of the American Foundrymen's Association*, vol. xxviii. pp. 117-120.

The process of the Arcade Manufacturing Company, Freeport, Illinois, for the preparation of moulding plates, is described.\*

S. Jones † describes a method of gating and moulding grids.

H. J. McCaslin ‡ describes a method of arranging moulds in groups in order to lessen the cost of production.

**Casting in Permanent Moulds.**—The casting of iron in cast-iron moulds is dealt with.§ Casting without a sand mould is not only applied to the Griffin process for the production of parts with a high surface hardness but a soft core, but also to the manufacture of such parts as bedsteads, balance weights for windows, brake shoes and other castings required on a large scale, when regular contraction or expansion is not of importance. Such castings cannot be annealed, and the percentage of silicon must be higher than for iron cast in sand moulds. The shape must be simple and the pieces must not be of too small dimensions. The moulds are expensive, and in spite of careful handling are frequently broken. With a small number of moulds a large number of pieces can be cast with little labour, and the surface of the castings is clean.

R. H. Probert || refers to the development of the use of cast-iron moulds and cores in iron-founding, and specifies the best kind of iron to use for the construction of such moulds.

**Moulding Machines.**—A. Greenhalgh, ¶ in dealing with gear-wheel moulding machines, gives illustrations and descriptions of the Buckley & Taylor and Whittaker machines. These are in principle dividing machines, fitted with the necessary adjustments for the moulding of the teeth of wheels, the spokes and boss of the wheels being produced by means of cores in the usual manner. The advantage of this class of machine lies in the equal pitching of the teeth and the economy of making a tooth-block, core-box, and striking-boards, as compared with the cost of a complete pattern, which would otherwise be employed.

A description is given \*\* of the Bridgeport power-ramming and power-lifting moulding machine. It is stated that with this machine 200 moulds per day are easily made, with important saving in weight.

Illustrated descriptions are given †† of a roll-over moulding machine and a jarring moulding machine designed by J. A. Murphy.

A description has appeared ‡‡ of the Curtis-Mumford overhead moulding machine.

\* *Giesserei Zeitung*, vol. vi. pp. 140-143, 237-240.

† *American Machinist*, vol. xxxii. Part II. pp. 146-147.

‡ *Canadian Machinery*, May 1909, pp. 59-62.

§ *Giesserei Zeitung*, vol. vi. pp. 148-149.

|| *Transactions of the American Foundrymen's Association*, vol. xxviii. pp. 47-53.

¶ *Foundry Trade Journal*, vol. xi. pp. 272-276.

\*\* *Iron Age*, vol. lxxiii. p. 1263.

†† *Ibid.*, pp. 1912-1913.

‡‡ *Ibid.*, pp. 1676-1677.

Descriptions and illustrations are given\* of various types of American moulding machines.

A method of machine moulding is described† by which both the upper and under sides of each part of the mould are impressed by a moulding machine. A number of such parts are then built up one on the top of the other, and the moulds are connected by a single vertical runner passing through all the boxes. In this way, instead of two parts being required for each mould, when making castings of one pattern, nine moulds can be built up out of ten parts. Illustrations of the machine and moulds are given.

R. Schmidt‡ describes the advantages of moulding machines for the production of castings for agricultural machinery. Parts moulded by machinery require less labour, are more regular in form, and require less fitting than those moulded by hand.

Avaurieu§ describes moulding machines operated by hydraulic pressure.

G. Muntz|| discusses machine and hand moulding, and deals with the requirements necessary for a successful universal moulding machine.

**Special Castings.**—A. Jude,¶ in a paper read before the Birmingham Metallurgical Society, draws attention to a peculiarity in a cylinder casting. The cylinder was of the type used in certain makes of high-speed engines, the high- and low-pressure cylinders, with steam-chest common to both between, being made in one casting. On examining one of these cylinders the author noticed, in one part of the casting, a peculiar dark streak. The thickness of the metal at this part of the casting was about  $\frac{7}{8}$  inch, and the streak appeared at a distance of about  $\frac{3}{8}$  inch from the surface which had been adjacent to the mould. It was suggested as a reason for this shell-like form that a kind of annealing process had taken place at this part. First, a hard skin had formed by the sudden cooling which the metal received from the mould and cores; afterwards the heat absorbed by the mould and cores caused an annealing action on the parts of the casting adjacent to them. As the casting was in this way kept below the critical temperature of the solidification of ferrite, the metal would undergo a kind of annealing which would change the combined carbon into the graphitic form.

F. Kerth\*\* discusses the manufacture of cast-iron sectional boilers for central heating.

J. Leber†† gives examples of very large pieces of work of different kinds that have been turned out, and the difficulties and risks attending the production of large castings are pointed out.

\* *Foundry Trade Journal*, vol. xi. pp. 430-431, 466-469, et seq.

† *Eisen Zeitung*, vol. xxx. pp. 421-425.

‡ *Giesserei Zeitung*, vol. vi. pp. 259-261, 298-302 et seq.

§ *Revue Mécanique*, 1909, pp. 22-52.

|| *Transactions of the American Foundrymen's Association*, vol. xxviii. pp. 105-111.

¶ *Foundry Trade Journal*, vol. xi. p. 470.

\*\* *Giesserei Zeitung*, vol. vi. pp. 264-266.

†† *Stahl und Eisen*, vol. xxix. pp. 621-628.

**Malleable Iron Castings.**—P. I. Giron \* states that it is characteristic of malleable cast iron that it possesses one or more of the attributes of all other metals or alloys; but as a rule, if any single property is present in a marked degree, the others will be correspondingly deficient. The tensile strength and ductility depend upon the method of production, and can therefore be controlled by the founder within limits wide enough to meet all conditions where the use of malleable castings is advisable. A malleable iron casting is to all intents and purpose wrought iron, and it is possible by taking advantage of this fact to effect a reduction of 30 to 50 per cent. in the weight of the casting as compared with ordinary grey iron castings serving the same purpose.

E. Schoemann † gives an illustrated general description of present-day malleable cast-iron practice, in which the furnaces and other plant are described in detail and the chemical compositions of the charges for different purposes are given and discussed. Analyses and test results of a series of samples of malleable cast iron are given in tabular form. The results obtained with open-hearth furnaces and cupolas respectively are compared, the former showing to greater advantage.

The manufacture of malleable castings is dealt with ‡ and illustrations are given of a 15-ton reverberatory furnace, a small acid-lined, open-hearth furnace, and a gas-fired annealing furnace.

W. H. Kane § deals with the construction of reverberatory furnaces for the manufacture of malleable castings.

**Steel Castings.**—L. Treubheit || points out that moulding as practised in the making of iron castings has not been much resorted to in the steel foundry, for the reason that this mode of working was not of a kind suited to the earlier steel castings made. When steel castings of other descriptions came into fashion, the foundries had become wedded to their primitive methods and were loth to give them up. He shows that the gradual fashioning of the lower mould by hand with partial patterns is speedier, cheaper, and better than the process in which a wooden pattern has first to be made, and necessarily gets wet and warps in use. He gives examples of operations in connection with a stern-frame, a rudder-frame, and a propeller boss respectively, and describes how first the lower mould is made, then the sand and loam pattern worked up, and finally the upper mould completed.

B. Stoughton ¶ gives detailed calculations as to the relative cost of electric steel-making processes compared with present methods in foundry work. A table is given showing the net cost of making steel castings by the various processes.

\* *Engineering Review*, vol. xx. pp. 403-404.

† *Stahl und Eisen*, vol. xxix. pp. 593-598.

‡ *Foundry Trade Journal*, vol. xi. pp. 460-464.

§ *Transactions of the American Foundrymen's Association*, vol. xxviii. pp. 23-29.

|| *Stahl und Eisen*, vol. xxix. pp. 824-830, 902-905.

¶ *Transactions of the American Foundrymen's Association*, vol. xxviii. pp. 217-226.

The electric process can hardly hope to compete in cost of production with any of the prevailing processes, except the crucible process, and then only when electric power is available at 3 cents per kilowatt hour or less. Recent developments in the electric process may, however, bring down the cost to the point where the converter process will be superseded, especially in view of the high quality of steel made by the electric process.

A. Stucki\* discusses the shrinkage of steel castings. He states that the shrinkage of a steel casting during solidification is  $\frac{1}{4}$  inch per foot, as against  $\frac{1}{8}$ -inch for cast iron,  $\frac{3}{16}$ -inch for brass, and  $\frac{5}{16}$ -inch for malleable iron; hence, patterns made for any of the other metals cannot be used for steel, even if the design would permit.

J. S. Unger† discusses the production of intricate shapes and thin-walled castings from steel made in the electric furnace.

**Casting Chains.**—Three methods of producing chains by casting processes are described and illustrated.‡

**Casting Chilled Car Wheels.**—T. D. West§ describes a new process for making chilled car wheels. Ordinarily, the chill or crust contracts about three-eighths of an inch within seven minutes of casting, which means that the outer or chilled rim of a car wheel contracts nearly its full amount while much of the internal body is still semi-liquid. The remedy suggested for uneven chill is to cause the metal to contract concentrically in the mould so that no part will remain in contact with the chill longer than any other.

**Faulty Castings.**—F. Hall|| deals with defects in castings, and suggests means of remedying them.

The production of bad castings in the foundry is dealt with, and methods are described by which wastage may in certain cases be prevented.¶

The principal causes of defects in castings and means for their prevention are also considered elsewhere.\*\*

**Cleaning Castings.**—H. R. Karg†† describes a sand-blast with an air-compressor. Compressed air and sand are led to the nozzle by separate pipes; the sand flows slowly from a holder placed above without appreciable wear of the pipe, and enters the nozzle tangentially. The compressed air develops a certain vacuum in the lower portion of the nozzle, which extends to the upper cyclone chamber of the nozzle and imparts a slight acceleration to the enter-

\* *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xxv. pp. 333-335.

† *Ibid.*, pp. 338-342.

§ *Iron Age*, vol. lxxxiv. pp. 390-391.

|| *Foundry Trade Journal*, vol. xi. pp. 283-284.

¶ *Ibid.*, pp. 479-480.

†† *Giesserei Zeitung*, vol. vi. pp. 136-140.

‡ *Foundry Trade Journal*, vol. xi. pp. 278-279.

\*\* *Engineer*, vol. cviii. p. 160.

ing sand. The acceleration is sufficient to distribute the sand regularly in the cyclone chamber and to lead it to the blast-pipe in the form of several streams, or of a single annular stream.

An illustrated description is given of a modern sand-blast apparatus for cleaning castings. It is worked on the principle of the injector, the air-pressure employed being 2 to 2.5 atmospheres.\*

**Accidents in Foundries.**—The final report of the committee of the American Foundrymen's Association appointed to consider the prevention of accidents in foundries has been published.† In a preliminary report it was stated that for a period of one year the total number of accidents in 1084 foundries was 5242, eleven of which were fatal. The report embodies the conclusions arrived at from a canvass of the foundry industry, and suggestions for the prevention of accidents in the foundry are given.

Illustrations are given of safety devices in use for the prevention of accidents at the works of some of the subsidiary companies of the United States Steel Corporation.‡

**Foundry Costs.**—W. Heym § deals with the costs of manufacture in the foundry.

\* *Eisen Zeitung*, vol. xxx. pp. 855-856.

† *Transactions of the American Foundrymen's Association*, vol. xxviii. pp. 55-68.

‡ *Iron Trade Review*, vol. xlv. pp. 173-176.

§ *Giesserei Zeitung*, vol. vi. pp. 273-276, 302-305 *et seq.*

## FORGE AND MILL MACHINERY.

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**Fluid Compression of Steel Ingots**—B. Stoughton \* discusses the physical quality of steel which has been subjected to compression during solidification. In the author's opinion compression during solidification lessens the liability of steel to contain the remnants of pipes, blowholes, segregation, and external cracks, and partially prevents the development of a weak structure during crystallisation. So far as is shown by tests it also increases the strength of finished steel and increases its toughness under impact, besides making the different parts of ingots more uniform in quality both before and after rolling.

J. F. S. Springer † describes the Harmet process for the compression of fluid steel.

A list is given ‡ of the European steelworks using the Harmet process for the solidification of steel ingots, the size of the presses being also given.

**Forging Presses.**—An illustrated description is given § of a new forging hammer designed to utilise the characteristics of the elastic gravitation blow for general smithy and forging purposes. In conjunction therewith is also shown a new creosote oil furnace for the rapid heating of the pieces to be drop-forged.

Details are given || of two high-speed hydraulic forging presses designed by Davy Brothers, of Sheffield.

An illustrated description is given ¶ of a 4000-ton hydraulic press, designed by the Watson-Stillman Company.

An illustrated description has appeared \*\* of the Bliss 3000-lb. compound pneumatic forging hammer.

B. Browning †† describes and illustrates a method of hydraulic forging for wheel hubs.

\* Paper read before the American Society for Testing Materials, June 29, 1909; *Iron Age*, vol. lxxiv. pp. 111-112.

† *Scientific American; Practical Engineer*, vol. xl. pp. 9-10.

‡ *Iron Age*, vol. lxxxiii. p. 1776.

§ *Engineering*, vol. lxxxvii. pp. 659-660.

|| *American Machinist*, vol. xxxii. Part I. pp. 628-630.

¶ *Canadian Machinery*, June 1909, p. 46.

\*\* *Iron Age*, vol. lxxxiv. pp. 24-26.

†† *American Machinist*, vol. xxxii. Part I. p. 705.

**Oil Furnaces for Rivet-heating.**—E. A. Allcut \* describes and illustrates a new oil-fired furnace designed by J. Ward for rivet-heating and bolt and nut manufacture. The fuel used is Texas oil of a calorific value of 19,250 British thermal units per lb., and costs about 4d. per gallon. The maximum temperature is attained with great rapidity, and the data given show a remarkable economy as compared with the cost of heating smithy hearths with coal.

**Gas Power for Driving Rolling-Mills.**—F. E. Junge † discusses the use of gas power for rolling-mills.

**Electric Driving of Rolling-Mills.**—A new cogging-mill, arranged on the Ilgner system of electrical driving, has been put into service at the Cleveland Wire Works of Dorman, Long & Co., Ltd., Middlesbrough. The rolls of the cogging-mill are 28-inch centres, and the normal maximum speed for which the plant is designed is 70 revolutions per minute. The motor for driving the rolls is connected by a short length of shafting to the pinion driving shaft, and is capable of giving a continuous output of 1200 brake-horse-power at 70 revolutions per minute, this corresponding approximately to a driving effort of 40 tons at 1 foot radius, or 34·5 tons at the periphery of the rolls. The motor also gives a maximum output of 3600 horse-power for short periods. Current is supplied to the motor from a flywheel motor-generator set consisting of one 950 horse-power, 2750 volt, 40 cycle, three-phase slip-ring induction motor, coupled to and mounted on the same base-plate as a 1000 kilowatt, 400 to 480 revolutions per minute, 400 volt, direct-current generator.‡

V. Graubner§ compares the cost of driving rolling-mills by steam and by electricity. He also describes a number of systems for the electric driving of non-reversing mills, and then gives an account of the latest practice in equipping reversing rolling-mills. Instances are given where the reversible driving motor is brought from rest to its full speed of 100 revolutions per minute in 2 to 2½ seconds, and starting and stopping can be repeated as often as 14 times per minute. The largest electrically driven reversing-mill is that at the Rombach ironworks, and some data of the performance of this mill are given. When rolling 3-ton ingots from a cross-section of 215 × 165 millimetres to one of 82 × 82 millimetres, the energy consumption per ton was 22·1 kilowatt hours including excitation. When working on ingots weighing 26 cwts., which were reduced from a section of 180 × 160 millimetres to one of 50 × 50 millimetres, the energy consumed amounted to 36 kilowatt hours per ton rolled.

G. Meyer|| in an extensively illustrated article, describes the electrification of a train of rolls, the steam-driven machinery of which

\* *University of Birmingham Engineering and Mining Journal*, vol. vii. pp. 150-153.

† *Iron Trade Review*, vol. xlv. pp. 892-898.

‡ *Times Engineering Supplement*, July 21, 1909, p. 19.

§ *Elektrotechnik und Maschinenbau*, vol. xxvii. pp. 381-386, 410-418.

|| *Stahl und Eisen*, vol. xxix. pp. 864-869.



was becoming worn out. The new plant is on the Ilgner system. A central station supplies continuous current of about 525 volts. A direct comparison between the costs per horse-power of the newer and older mills proved almost impossible on account of the varying conditions of working, cost of fuel, &c. The chief advantage was found to lie in the centralisation of the power-producing machinery which the application of electricity rendered possible.

A description is given \* of a 2000 horse-power three-phase motor which has been installed by the Felten Guillaume Lahmeyerwerke at Völklingen. This motor runs at 100 revolutions per minute with 5000 volts pressure and a frequency of 50, and can be used alone or in conjunction with a 3000 horse-power gas-engine for driving the roughing rolls, the finishing mill being driven by ropes from the roughing mill.

R. Tschentscher † deals with some problems in the application of electric power in steelworks, and gives a general description of the electrical machinery which has been installed at the works of the Illinois Steel Company, South Chicago, consisting of a generating equipment of 29,000 kilowatts, and about 2000 motors, with an aggregate horse-power of 75,000.

W. F. Mylan ‡ has contributed a paper on the best method of estimating for the electrical equipment of an existing steam-mill. The various conditions affecting the design of the flywheel, and the methods of regulating the speed where an induction motor is used, are discussed. Particulars are given of mills where the conversion to electric driving has been successfully carried through.

E. W. Yearsley § deals with the practical requirements of rolling-mill motors. The author considers the control apparatus to be the weakest part of the electrical system at present, and that more tests on present installations are advisable in order to obtain a better knowledge of the power and speed requirements of rolling-mills, so that flywheels could be better designed to equalise the loads.

J. Blažek || discusses the various devices employed for the equalisation of the load in electric machines for driving rolling-mills, with special reference to the Ilgner flywheel apparatus.

H. C. Specht ¶ discusses the functions of flywheels in electrically driven rolling-mills, and deals with specific cases of designing fly-wheel capacity to give, as nearly as possible, with a rolling-mill motor, a constant motor load equal to the average of all the loads on the rolling-mill driven by that motor.

\* *Elektrotechnische Zeitschrift*; *Electrician*, vol. lxii. p. 486.

† Paper read before the American Institute of Electrical Engineers; *Engineer*, vol. cviii. p. 343.

‡ *Journal of the Institution of Electrical Engineers*, vol. xliii. pp. 488-508.

§ Paper read before the American Institute of Electrical Engineers; *Engineer*, vol. cviii. p. 200.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lvii. pp. 505-510, 524-530, 540-542, 555-557, 567-572.

¶ Paper read before the American Institute of Electrical Engineers; *Engineering News*, vol. lxii. p. 50.

Maleyka \* collects data from various publications, and by the help of diagrams discusses the motor power necessary for cogging-mills and bar iron mills of various types and sizes.

E. K. Scott † discusses the advantages of the direct-current and three-phase motors for rolling-mills.

C. T. Henderson ‡ discusses the subject of electric control for rolling-mill motors.

E. Friedlander § discusses the advantages of electric driving of rolling-mills. The electric drive has shown how to get the best relation between rotating masses, speed, time, and horse-power. The watt-hour meter indicates that lower heat, greater elongation, and especially change of profile in different directions increase the power required at the rolls much more rapidly than hardness, high tensile strength, or larger draughts. With electric motors the problem of reversing rolls becomes simpler, and the shocks in rolls and couplings are greatly lessened. The direct-current motor, on account of its load and speed characteristics, is better adapted for driving rolls than the alternating-current motor. For reversible roll-driving direct current is used exclusively.

B. Wiley || gives the results of tests made with an electrically driven merchant mill in order to ascertain the power requirements for rolling high-carbon steel of small section. The mill in question was a 9-inch merchant mill consisting of seven stands of three-high rolls and one finishing stand of two-high rolls, driven by a two-speed, two-phase, 60-cycle, 2200-volt induction motor of squirrel-cage construction. The ratings of the mill are 600 horse-power at 600 revolutions per minute (synchronous speed), and 450 horse-power at 450 revolutions per minute. The product of the mill is of comparatively small section.

H. Groeck ¶ reviews Ortmann's experiments made for determining the power consumption of electrically driven and steam driven non-reversing and reversing rolling-mills.

G. A. Merkt \*\* describes a method of calculating the power consumed in a roll pass.

**British Rolling-Mills.**—An illustrated description has appeared †† of a plant for rolling sections, recently erected at the works of the Pather Iron and Steel Company, Wishaw.

An illustrated description is given ††† of a compound condensing engine used for driving the sheet-mills at the Eclipse Works, Glasgow.

\* *Stahl und Eisen*, vol. xxix, pp. 1427-1430.

† *Iron and Coal Trades Review*, vol. lxxix, p. 389.

‡ Paper read before the American Institute of Electrical Engineers; *Iron and Coal Trades Review*, vol. lxxix, p. 655.

§ *Proceedings of the American Institute of Electrical Engineers; Electrical Engineer*, vol. xlv, pp. 31-32.

|| *Proceedings of the American Institute of Electrical Engineers*, vol. xxviii, pp. 773-781.

¶ *Zeitschrift des Vereines deutscher Ingenieure*, vol. liii, pp. 822-828.

\*\* *Iron Trade Review*, vol. xlv, pp. 758-760.

†† *Iron and Coal Trades Review*, vol. lxxviii, pp. 1011-1013.

††† *Ibid.*, pp. 539-540.

**Russian Rolling-Mills.**—The gas-engine-driven rolling-mill plant at the works of the Société Metallurgique Russo-Belge, at Enakiewo, Russia, is described and illustrated.\*

**Rolling-Mills in India.**—The rolling-mill plant of the Tata Iron and Steel Company, Bombay, is described.†

**Bray Continuous Mill.**—W. Schnell ‡ describes the installation of the Bray continuous plate-mill in the United States.

**Mill Accessories.**—An illustrated description has appeared§ of the Watson-Stillman hydraulic shears for heavy work. The machine shears at any angle, and can be adapted for any-sized work. At present two sizes are made, suitable for 15-inch and 24-inch beams respectively. The weight of the smaller machine is 12,000 lbs., and that of the larger 16,500 lbs.

An illustrated description|| has appeared of what is claimed as being the largest steel lever shear in the world. It has been built for the Gary works of the Indiana Steel Company, by the Mesta Machine Company, Pittsburgh. It is of the low knife design, and will make twelve cuts per minute of cold steel 6½ inches square or 7 inches round. Except the flywheel, the whole of the parts are made of steel castings. The knives are 36 inches long, and the weight of the machine, excluding motor, is 225,000 lbs.

\* *Iron and Coal Trades Review*, vol. lxxix. p. 381.

† *Ibid.*, p. 465.

‡ *Stahl und Eisen*, vol. xxix. pp. 380-384.

§ *Iron Age*, vol. lxxxiv. pp. 535-537.

|| *Ibid.*, p. 846.

# PRODUCTION OF STEEL.

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### I.—THE CARBURISATION OF MALLEABLE IRON.

**Manufacture of Steel in Crucibles.**—V. Stobie,\* in dealing with crucible steel melting, investigates the functions of the different types of furnace, and compares their merits as regards cost of melting and adaptability to the melter's requirements.

W. J. May † discusses the causes of failure in crucibles, and gives suggestions for their handling and treatment.

### II.—THE OPEN-HEARTH PROCESS.

**New Form of Open-Hearth Furnace.**—C. Brisker ‡ is the inventor of a double open-hearth furnace, which, resting upon rollers, can be tilted to such an angle that the molten metal can flow from one of its divisions over the low partition into the other. A charge in division A, which is already decarburised, is to be freed from its ferriferous slag to enable the final refinement to be made. For this the hearth is tilted so that the slag flows from division A into division B. Here the lining has already been prepared for the fresh charge. After the introduction of the slag the fluid pig iron is poured in and undergoes refinement, the slag thereby parting with its iron. The charge in A is meanwhile tapped. The process is a continuous one, and as the slag accumulates, part of it has to be removed after it has parted with its iron. It is tapped by tilting the hearth after the finished charge has been withdrawn.

\* *Iron and Steel Times*, vol. i. pp. 167-171.

† *Foundry Trade Journal*, vol. xi. pp. 277-278.

‡ *Stahl und Eisen*, vol. xxix. pp. 1139-1143.

**Open-Hearth Furnace Practice.**—M. A. Pavloff \* gives a short account of the ore process carried out in the open-hearth plant of the Dneprovsky Works, South Russia. The working results of one of the open-hearth furnaces at those works are given for April 1909 :—

*Number of Heats made in Twenty-eight Working Days = 100.*

Metal charged.	Tons.	Material used.	Tons.
Molten iron . . . .	3832.22	Ore . . . . .	876.39
Solid iron . . . . .	104.55	Dolomite . . . . .	203.94
Steel scrap . . . . .	239.10	Limestone . . . . .	432.2
Additions (ferro-manganese) .	13.76	Coal . . . . .	824.47
Total metal . . . .	4189.63		
			Tons.
			4162.73
			136.04
			Total steel obtained . . . .
			4298.77

The iron, taken in a molten state from the mixer, is the product from the red hæmatite of Krivoi Rog, with small proportions of mill cinder, and open-hearth and Bessemer slag, and has the following composition :—

	Per Cent.
Carbon . . . . .	3.75
Silicon . . . . .	0.7 to 1.8
Manganese . . . . .	1.2 to 2.1
Sulphur . . . . .	0.05
Phosphorus . . . . .	0.15 to 0.40

As an oxidising agent very rich Krivoi Rog hæmatite is used containing 93 per cent. of iron oxide. The fuel consumption is not excessive, considering that the coal used contains often 12 per cent. of ash and 6 per cent. of moisture.

W. M. Carr † deals with the use of small open-hearth furnaces for the production of steel for castings, and compares its advantages with furnaces of a larger type. It is claimed for the small furnace that it costs less to install than any other steel-making device, with the exception of crucible melting furnaces, that it is economical in operation, and that there are more certain results, a greater degree of control in operation, and a reduction of the personal equation to the lowest possible degree. An outline of the method of operation of a miniature open-hearth furnace is given.

B. Stoughton ‡ discusses, and gives details of the cost of the manufacture of steel by the acid open-hearth, the converter, and the

\* *Engineer*, vol. cviii. p. 216.

† *Transactions of the American Foundrymen's Association*, vol. xxviii. pp. 31-38.

‡ *Ibid.*, pp. 217-226.

basic open-hearth processes; by the acid and basic open-hearth processes making small castings, and by the crucible and electric processes.

The development of the open-hearth process is dealt with.\*

H. G. Martin † points out that samples of fluorspar may contain up to 10 per cent. of barium sulphate. Not only does the presence of this impurity necessarily lower the calcium fluoride value of the spar, but it is far more deleterious than either high silica or high percentages of carbonates. A method for the detection and quantitative estimation of the barium sulphate present is detailed.

**Scrap for the Open-Hearth Process.**—M. Orthey ‡ points out the great variation in the chemical composition of deliveries of scrap from abroad for metallurgical purposes. Tables are given of the different proportions of the chemical constituents found by analysis to be contained in different waggon-loads of the same delivery. The advice is given to have the material of such deliveries analysed whenever the quality of the ultimate product is of importance.

**British Steelworks.**—An illustrated description of the Parkhead Steelworks has appeared.§ A completely new ordnance factory for the manufacture of guns up to 12 inches in calibre has been equipped, and in recent years the steel furnaces have been renovated and hydraulic presses have been laid down for the fluid compression of steel.

The equipment of the Atlas Steelworks, Sheffield, for the manufacture of armour plate is briefly described.||

A long account, with illustrations, is given of the works of the Cargo Fleet Iron Company at Middlesbrough, all the newest installations being described.¶

A description is given \*\* of the steel and tinplate works of Richard Thomas & Co., of Llanelli.

**Indian Steelworks.**—An illustrated description is given †† of the works of the Tata Iron and Steel Company, Bombay. The steel plant is accommodated in a building 650 feet by 135 feet, containing one 300-ton gas-fired mixer resting in cradles; four 40-ton basic open-hearth furnaces, and three five-hole gas-fired soaking pits. All the furnaces are equipped with Dyblie water-cooled reversing valves. The metal is brought in ladles from the blast-furnace plant, and is poured into the mixer by one of the two 75-ton casting cranes. The

\* *Iron and Steel Times*, vol. i. pp. 308-309.

† *Journal of Industrial and Engineering Chemistry*, July 1909; *Iron Age*, vol. lxxxiv. pp. 392-393.

‡ *Stahl und Eisen*, vol. xxix. pp. 507-512, 552-555.

§ *Engineering*, vol. lxxxvii. pp. 439-442, 513-515, 580-582, 656-658, 689, 751-754.

|| *Times Engineering Supplement*, July 21, 1909, p. 17.

¶ *Génie Civil*, vol. liv. pp. 367-396.

\*\* *Iron and Coal Trades Review*, vol. lxxix. p. 126.

†† *Ibid.*, pp. 464-465.

ingots are cast in moulds standing on trucks. At the east end of the steel plant is the stockyard, served by a 10-ton travelling crane. All the cold stock is charged into the furnace by an overhead charging machine. The ingot moulds are stripped and charged into the soaking pits by special overhead charging and drawing machines.

**American Steelworks.**—D. A. Lyon\* describes the equipment of the Noble Electric Steelworks, California.

**Steelworks Equipment.**—A description of the electrical equipment of the Lanarkshire Steel Company, Ltd., is given.† In addition to their private electric installation of about 400 kilowatts capacity, the firm has recently brought in a supply from the mains of Clyde Valley Power Company for the purpose of driving the hydraulic pumping plants, cranes, and auxiliary machinery of the rolling mills.

A description is given‡ of a machine employed for stripping the ingots from the mould, in addition to charging and withdrawing the ingots from the soaking pits.

An illustrated description is also given elsewhere§ of a machine for charging blooms into and withdrawing them from the reheating furnaces.

An illustrated description is given|| of the Newton cold saw.

### III.—THE BESSEMER PROCESS.

**Duplex Process.**—Experiments on the duplex process of steel-making have been carried out at the Southside works of the Jones and Laughlin Steel Company, Pittsburg.¶ This process is a combination of the present standard Bessemer and basic open-hearth processes. The molten pig iron is first placed in a Bessemer converter and subjected to blowing, which is continued for about one-half the length of time required in the ordinary Bessemer practice. The partially prepared steel is then placed in the basic open-hearth furnace, and the steel-making operation is completed in the usual manner under this process. By means of this double process it is possible to use pig iron, high, within practicable limits, in both silicon and phosphorus. By the Bessemer converter the silicon is reduced to the proper proportion, and through the basic open-hearth action a similar effect is produced upon the phosphorus. The principal reason that prompted

\* Paper read before the American Electrochemical Society, May 1909; *Electrochemical and Metallurgical Industry*, vol. vii. p. 252.

† *Electrical Engineering*, vol. v. pp. 913-914.

‡ *Iron and Coal Trades Review*, vol. lxxix. p. 626.

§ *Ibid.*, p. 131.

|| *Iron Age*, vol. lxxxiii. pp. 1914-1915.

¶ *Iron Trade Review*, vol. xlv. p. 1150.

the experiments is based upon the recognition of the declining importance of the Bessemer process, the object in view being the continued utility of the Bessemer plant, which consists of three converters. It is believed that the combination of the two processes may be developed into producing an increased steel tonnage over that turned out by the same plants working singly.

C. Rott \* expresses confidence in the future of the Bessemer converter for the production of steel for castings, and predicts that it will find its place beside the electrically worked open-hearth furnace. He describes and gives illustrations of a small Bessemer plant erected by him in Styria. The plant in question can deal with ten charges per day, and high qualities of cast steel of different kinds can be produced by it.

P. Eyermann † deals with the use of the small Bessemer converter for the manufacture of steel castings.

J. S. Whitehouse ‡ discusses the use of the side-blow converter for steel castings.

**Blowers for Converters.**—F. Hartig § gives particulars of an electro-motor of 2000 horse-power which is used for driving the converter blowing apparatus at the Peine steelworks. The twin blowing-engines are of the horizontal double-acting type. The effective surface of the blowing piston is 17,500 square centimetres. Extensive tables give full particulars of the performance of the blast, and of the electric machinery. The efficiency of the blower was found to be 92 per cent., and that of the motor 94·4 per cent.

**Basic Slag.**—The use of basic slag for fertilising purposes, its composition, and the methods of grinding and preparing it, are considered by R. P. Skinner.||

G. Meyer ¶ gives an account of the use of basic slag in agriculture.

J. Hendrick \*\* deals with the amount of free lime found in basic slag. The results show that the percentages of free or caustic lime commonly stated to be present in basic slags are not found in the slags at present on the British market. As a rule the amount of free lime present is under 2 per cent., and it is often under 1 per cent. Tables are given which indicate that the basic lime in slag is not only a very variable quantity, but that it consists of lime in various forms of combination, such as silicates and basic phosphates. As the conditions are very complex, it is impossible to draw any line and state an exact percentage of basic lime in slag except in terms of a strictly defined method of determining it.

\* *Stahl und Eisen*, vol. xxix. pp. 1190-1192.

† *Iron Age*, vol. lxxxiii. pp. 1998-1999.

‡ *Transactions of the American Foundrymen's Association*, vol. xxviii. pp. 69-72.

§ *Stahl und Eisen*, vol. xxix. pp. 1049-1059.

|| *Mining World*, vol. xxx. p. 729.

¶ *Stahl und Eisen*, vol. xxix. pp. 1488-1490.

\*\* *Journal of the Society of Chemical Industry*, vol. xxviii. pp. 775-778.



**History of the Basic Process in Germany.**—J. Massenez \* has contributed a retrospect of the development of the basic process in Germany during the last thirty years.

It is precisely thirty years since the first charge was blown in a basic converter in German works, and the success which has attended the introduction of the process furnishes a striking commentary on the incredulity with which, at the spring meeting of the Iron and Steel Institute in 1878, the announcement of the invention by S. G. Thomas was met. On the 4th of April 1879, a demonstration of the process was given at Middlesbrough, at which E. Meier and R. Pink were present, armed with authority to negotiate the patent rights for Germany, but found that they had been forestalled by G. Pastor. An arrangement was ultimately made between the representatives of the Rheinische and the Hörde works to acquire the patent rights for Germany and Luxemburg, and later the representation of those rights for Austria and Hungary was secured by the latter company.

The early difficulties met with included that of finding a suitable material for the basic bricks, but this having been circumvented, the first charge was blown simultaneously both at Hörde and at the Rheinische works on September 22, 1879, the converter, at the latter works, which belonged to the old Bessemer plant, having a capacity of 3 tons. On the same day, the first basic rails were rolled on the Continent, and were found perfectly satisfactory. The results were reported at a meeting of the German Ironmasters' Association in December 1879, and on the basis of a number of analyses of charges, it was shown that silicon may be advantageously replaced in pig iron by phosphorus, and that the silicon content can be kept low without any great loss of iron, a suitable proportion of the silicon being eliminated even when the bath contains manganese as well, and no further doubt was left in Germany as to the technical practicability of the process, although economic considerations still stood in the way of its adoption. The experience gained in its operation, however, led to numerous large basic steelworks being equipped with the necessary plant for the process, and many experiments were made to obtain a durable lining for the converter, trials being made with pressed bricks of calcined dolomite, and with magnesia bricks. The durability of bricks made from the latter material, however, was not sufficient to compensate for the higher cost of production. About this time litigation commenced, with the object of testing the validity of the Imperial patents, but, after a long hearing, the patent rights were upheld, and, although many appeals were lodged, the High Court continued to decide in favour of the licencees. The result stimulated further investigation of other methods for the elimination of phosphorus, although these attempts neither furthered nor retarded the extension of the process, and the production of basic steel continued to increase annually, one of the leading improvements being the introduction of the pig-iron mixer, which originated simultaneously in America and

\* *Stahl und Eisen*, vol. xxix. pp. 1465-1477.

Germany, and was found excellently adapted for the desulphurisation of the pig iron.

Soon after 1890 the mixer, in one form or another, was to be found in all basic steelworks, and it was solely through the use of these large vessels—one of which, holding 1000 tons of molten metal, has recently been erected at the Gutehoffnungshütte—that basic steelworks were enabled to operate rapidly with the increased certainty of obtaining a uniform product, and turning out the heavy outputs now made. A tribute is paid to the work of J. E. Stead on the chemical side of the process, and to his extensive and elucidatory researches on the theory of the process, and reference is also made to the investigations by other observers, both in Great Britain and in Germany and Austria.

Of all industrial countries, Germany and Luxemburg derived the greatest benefit from the basic process, these being followed in order by France, Austria, and Belgium; whilst in England its development was retarded. The immense ore deposits in Luxemburg and Lorraine form the chief basis of the extensive prosperity of Germany's production of mild steel. The great advantage of the basic process in the case of works in other parts of Germany, where less extensive deposits of phosphoriferous ores exist, as, for example, the Ilse works and the Maximilianhütte, is also well known. In Austria-Hungary it came chiefly under consideration for the Bohemian iron industry, and also for the Moravian and Silesian works. The process was first put into regular operation at Witkowitz, and soon after it was established at Kladno, where preliminary trials had already been made in March 1879, as well as at Teplitz and at Trzynietz, near Teschen. Whereas up to that time the Austrian Alpine provinces had produced the greater portion of the steel made in that country, owing to their excellent spathic ironstone, the figures soon changed to the advantage of the first-named provinces, where the local iron industry was able to use cheap phosphoriferous ores and cheap fuel. The first exhaustive report on the working of the basic process in Austria was drawn up in May 1880 by a Commission consisting of P. von Tunner, F. Kupelwieser, A. Krautner, and three other gentlemen.

The chief cause of the slow development of the process in England was that the composition of the greater portion of the phosphoretic ores in Great Britain was not so well adapted for the production of basic pig, especially the Cleveland ores, with their high percentage of silica and alumina, and comparatively low content of phosphorus. In order to reduce the sulphur content of Cleveland ore to a permissible level in the pig iron, it is necessary to smelt at a high temperature in the blast-furnace, and thus to produce grey iron, high in silicon and low in phosphorus. On this account, the makers of basic steel in England, who used Cleveland pig, worked for a considerable time under less favourable conditions than the continental steel-makers. The lining of their converters corroded more rapidly; they were obliged to add larger quantities of basic materials in order to obtain a strongly

basic slag, and considerable waste of iron was incurred. These disadvantages were afterwards remedied, either by adding manganiferous ores in making the pig iron, in order to obtain a manganiferous iron low in silicon, and, more recently, by a modification of the process, in which only just sufficient basic adjuncts (preferably lime and iron oxides) are placed in the converter at first, to produce, by the burning off of the silicon in the first stage of the process, a slag of the requisite fluidity, yet at the same time too acid to take up any appreciable quantity of phosphoric acid. After pouring off this slag as completely as possible, the extra lime required is added, and the charge is dephosphorised and finished. Hence the slow extension of the basic process in England was not due to international restriction in order to maintain the predominance of the Bessemer plant, but rather to the difficulties caused by the chemical composition of the phosphoretic ores available there. In the same way, contrary to a widespread belief, the introduction of the basic open-hearth process in a number of works in the United States was due, not because it was expected to furnish any special qualitative or economic advantages, but on account of the simpler, but nevertheless more forcible reason, that the composition of the available ore was apparently unsuitable for refining by an acid process.

The production of ingot steel by the basic open-hearth process was also greatly benefited by the introduction of suitable basic bricks, since it enabled phosphoretic raw material to be converted into excellent ingot iron in basic-lined open-hearth furnaces. In view of the success of basic lining in the converter, it is not surprising that this improvement should also have been applied to the open-hearth furnace. It is nevertheless remarkable, that no patent should have been taken out for this application, the probable reason being that the first dephosphorisation in the open-hearth furnace, that was carried out at Alexandrowsky, near St. Petersburg, was not made the subject of an application for a patent, but rendered public property by publication in the technical press.

Rails formed the first product made from the new material, and its high ductility soon demonstrated its suitability for wire drawing, while it was also largely adopted for sections. Its use in the manufacture of rail steel is demonstrated by the fact that as the result of a general inquiry in 1889 respecting the character of German rail material, it was shown that the percentage of ingot steel rails rejected on account of unsuitability, during the time covered by guarantee, was extremely low, the average being only 0.02 to 0.03 per cent. The number of broken rails was exceedingly small, and the only instances of increased wear have been explicable by the special circumstances of each case.

As an instance of the esteem in which the process was held, almost from its inception, may be quoted a passage in a letter written by J. Massenez, as far back as October 1879, in which he stated that: "Up to now not a single charge has failed to furnish usable steel; and most of the charges have given a product that could not be equalled by that of the best grades of hæmatite pig iron." He goes on to say

that the process will revolutionise nearly all the existing principles in the domain of ingot steel manufacture, as German industry is thereby liberated from dependence upon English hæmatite, and upon African and Spanish ores.

G. Hilgenstock \* also contributes an account of the early difficulties in the adoption of the process, and the means whereby they were overcome. The first real progress was made when the travelling ladle was introduced. This step did away with what might be called the mixed steel process, previously employed in the blast-furnace and the cupola, which were worked in collaboration. The desulphurising influence of the use of the ladle, and also that of the mixer, contributed greatly to the success of the process. The value of the slag, however, had not then been recognised, and this discovery is best told in G. Hilgenstock's own words.

"In walking one Sunday afternoon past the blocks of basic slag, which I had caused to be tipped by themselves, and not on the waste heap, I observed on several broken blocks a surprising number of beautiful crystals. Making a careful selection of these, I sent them next day to be examined, at our laboratory, for lime and phosphorus, suspecting them to consist of the same stable phosphate of lime that is formed during the basic process. Our particularly careful head chemist determined the proportions of lime and phosphoric acid, which, to the general surprise, turned out to correspond, not to the triphosphate, but approximately to the phosphate containing four molecules of lime to one molecule of phosphoric acid ( $\text{Ca}_4\text{P}_2\text{O}_9$ ). This discovery of the tetrabasic calcium phosphate was published in *Stahl und Eisen* for September 1883.

"The discovery stimulated me at the time to numerous experiments and investigations into the composition of basic slag and to many rapid tests, to which my work in the laboratory is naturally restricted at all times. The result of our labours was my paper on the composition of basic slag, read at the meeting of the *Eisenhüttenleute* in 1886."

A. Spannagel † also deals with the same subject, with special reference to its later developments, and to the recarburising processes, which have since been introduced.

According to the Aachener-Hütten-Verein, ‡ the following are the chief technical improvements that have been made in German practice since the introduction of the process.

1. The introduction of the various types of mixer.
2. The application of gas motors for the blowing-engines.
3. The gradual increase in the size of the converters, up to charges of 25 tons, the depth of the bath being kept low, and thus lessening mechanical projection.
4. The improvement in the application of the blast, by distributing it over a larger number of correspondingly smaller holes in the bottom, thus lessening waste of metal.

\* *Stahl und Eisen*, vol. xxix. pp. 1478-1483.

† *Ibid.*, pp. 1483-1486.

‡ *Ibid.*, pp. 1486-1487.

5. The partial use of magnesite tuyere bottoms to increase the durability of the bottoms.

6. The increase of pressure up to 500 atmospheres in moulding the bricks.

7. The application of compressed air for back ramming the basic converter lining.

8. The use of a device for rapidly cleaning away incrustations in the mouth of the converter.

9. The introduction of portable pouring ladles.

10. The casting of the steel in portable ingot moulds.

The most important contribution to rapid working is afforded by the constantly increasing durability of the converter lining and bottom. A circular, addressed to the managers of basic works, has elicited the fact that the maximum life of the converter lining varies between 204 and 350 charges, corresponding to an output of 3750 to 5250 tons of crude steel. The highest durability of the needle bottoms is between 58 and 102 charges, and that of the tuyere bottoms, 130 to 266. The very small consumption of basic material with which the work can now be carried on is shown by the following communication from the Rothe Erde Works. In June 1909 236 charges were blown in one converter, whereupon the lower part was relined, and another 246 charges were blown. The lower part was then again relined, still retaining the old upper lining, and 220 additional charges were blown. Thus 720 charges, yielding about 14,700 tons of ingot steel, had been blown in this converter before it needed entirely relining, so that the consumption of basic material was rather less than 20 lb. of calcined dolomite per ton of steel produced. The high daily output of German basic steelworks is largely rendered possible by the above-mentioned increase in the durability of the lining. The maximum output at individual works, per double shift of twenty-four hours, was 1100, 1226, 1280, 1480, 1505, 1585, 1635, 1935, 2000, and 2260 tons of ingot steel respectively.

P. Martell \* has contributed an interesting article on the history of the Bessemer process, and a review of the inventions of Sir Henry Bessemer.

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#### IV.—ELECTRIC PROCESSES.

**The Development of the Use of Electricity for the Refining of Steel.**—C. C. de Coussergues † describes at length the progress of electric refining of steel, and the present state of the industry, the origin of which he traces to the need for utilising the surplus electrical energy available, in the first instance, at aluminium works, and those manufacturing ferro alloys. Prior to this, however, events had fore-

\* *Giesserei Zeitung*, vol. vi. pp. 175-179.

† *Revue de Metallurgie, Mémoires*, vol. vi. pp. 589-679.

shadowed the employment of electricity for metallurgical operations, and one of the earliest patents was taken out in 1853. In 1879 Siemens invented an electric furnace, and in 1885 Ferranti patented the principle of induction furnaces, while it was Moissan who, in 1892, indicated the possibilities that existed in this direction. It has only been, however, since the commencement of the twentieth century that furnaces intended for the manufacture of steel on an industrial scale have come into being, the electric furnace having been up to then regarded only in the light of a means of producing steel of the crucible type. The underlying principles of the chief forms of furnace in use are then described, and the furnaces themselves are classified and illustrated, after which complete details are given of those actually in industrial operation at the present time. These include the Stassano furnace, the Girod furnace, the Giffre and Allevard furnace (Chapelet system), the Hérault furnace, and the special type of the latter in use at Remscheid. These constitute the chief industrial types of electrode furnaces, after which induction furnaces are similarly described and illustrated. This category includes the Roebling furnace, and one or two modifications thereof. Each of the descriptions of the foregoing furnaces is accompanied by illustrations of the furnaces themselves, and diagrams of their construction. The actual practice followed at the leading works is then described, details of the charge and of the method of working it throughout being given, together with analyses of the raw materials, the end product, and the slags. The works respecting which such details are given are Allevard, Turin (Stassano), Bonn, Ugine, La Praz, Remscheid, and Völklingen, and the descriptions of the operations are followed by a summary of their leading features and a discussion of the functions and composition of the various slags produced in each, the general circumstances attending the working of the charges by the different processes being fully compared and discussed.

Attention is next directed to the chemical reactions involved, a section being devoted to the removal of carbon, silicon, manganese, and phosphorus, and a further section to the removal of sulphur, and of oxygen. Each of these operations is discussed at length, both in their theoretical aspects and in their practical bearings, and diagrams and analytical tables showing the composition of the slags produced at different stages of working are given.

The next point considered is that of cost. Here the various factors are passed under review, and considered generally, after which the actual working costs at various works are given in detail, with tables of the kilowatt consumption of electricity for each stage of the reduction, corresponding with scheduled times showing how long the various stages last, and the allocation of the consumption of electrical energy during each stage. These details apply respectively to the practice at Turin, Ugine, La Praz, Remscheid, and Völklingen, and are supplemented by a discussion of the general conditions and costs of repair and maintenance at the different works. Finally the nature of the resulting product is considered, and tables are given showing the

chemical composition and mechanical properties of the steel produced at La Praz, Ugine, Völklingen, and Turin.

The general conclusions drawn from the foregoing considerations are as follows: Electro-metallurgy has against it, at the present time, the high cost of the electric calorie, a high cost which is not compensated for by the efficient use made of it in electric furnaces, which it is difficult to conceive as likely to be increased in the near future. This notwithstanding, the application of electricity to the manufacture of iron and steel is likely greatly to increase for the following reasons. At the present day, in order to obtain the kilowatt corresponding to 857 calories, it is necessary to consume from 1200 to 2000 kilogrammes of coal, corresponding with 9000 to 16,000 calories. Thus, so long as engineers fail to improve the yield indicated by these figures the electric furnace can only be of advantage in cases where its metallurgical qualities are such as to compensate for the larger expenditure of heat energy, exception being of course made for countries where the cost of coal is very heavy, and hydraulic power cheaply obtainable. In the latter circumstances the development of electro-metallurgical methods is certain provided the necessary supply of raw material and the demand for the finished product are duly forthcoming. Otherwise electric furnaces can only be expected to progress owing to their metallurgical qualities, in the forefront of which must be placed the possibility of obtaining very special steels, and crucible qualities, without employing crucibles, and the facility with which deoxidation of the metal can be achieved; in short, the ease with which they can be operated, the low cost of heating them up and the low cost of their installation in circumstances where available supplies of electricity from an existing power plant are accessible. The electric furnace, thanks to its successful application as an instrument of alternate oxidation and deoxidation may already be regarded as a possible means of cheaply refining basic metal.

P. M'N. Bennie\* reviews the progress and present position of the electric furnace.

**Metallurgy of the Electric Steel Furnace.**—F. W. Harbord † reviews recent developments in the practice of electric smelting, and describes the various forms of induction, resistance, and arc furnaces. Where pure materials can be procured, as in Sweden, and pure scrap and pig iron can be mixed together in such proportions as to give a steel of the required composition, the original Kjellin furnace has, in the author's opinion, much to recommend it. If, on the other hand, the raw material is ordinary miscellaneous scrap, it is necessary (1) to have a furnace in which extremely basic slags can be retained in a fluid state to refine the metal, and (2) to remove these slags when desired, and to add basic materials to form new slags

\* Paper read before the Engineers' Society of Pennsylvania, June 10, 1909; *Engineering and Mining Journal*, vol. lxxxviii. p. 84.

† *Journal of the West of Scotland Iron and Steel Institute*, vol. xvi. pp. 173-206, 212-221.

to purify the metal completely. The furnaces that fulfil these requirements are the Héroult, Girod, Stassano, and Röchling-Rodenhauser. The electric furnace is considered to be costly for melting purposes, but economical for refining at those high temperatures when the reaction between the slag and the metal is most effective. Dealing with the smelting of iron ores, the author states that from the standpoint of Great Britain the direct smelting of iron ores in the electric furnace is of little practical importance, as, although considerable advances have been and are being made, the conditions existing in this country are such that the electric furnace cannot compete with the blast-furnace.

H. M. Howe\* discusses electric smelting practice, with special reference to the removal of carbon, phosphorus, and sulphur. He points out that the processes carried out in electric furnaces are not really "electric processes," as electricity is used solely as a source of heat, and purification is brought about in the same manner as in older processes, such as puddling, or Bessemer, open-hearth, or even blast-furnace practice. Electric furnaces may be regarded as large internally heated crucibles, or, to use a Hibernianism, as "closed" open-hearth furnaces, in which the flame is replaced by electric arcs, currents of electricity, or both. Treatment proceeds in three distinct stages: (1) melting down; (2) oxidising the phosphorus of the molten metal and its carbon and silicon, if any excess of these elements be present, by means of iron oxide; and (3) removing suspended slag, and deoxidising and desulphurising by means of carbon, ferro-silicon, aluminium, or, more effective than all, by forming calcium sulphide in the furnace itself. This third step is the only one peculiar to the electric furnace, as the two former can be, generally speaking, carried out more cheaply by other means. The special circumstances attending smelting in arc and in induction furnaces respectively are then discussed and compared, after which special attention is devoted to the various purification processes from a metallurgical point of view. A warm tribute is paid to the work of C. C. de Coussergues in elucidating this aspect of the subject. Whether dephosphorisation shall or shall not occur depends upon the balance of several opposing forces, yet the matter can be simplified by discriminating between slags which actively dephosphorise and those which are simply retentive of phosphorus, or, in short, between the dephosphorising and non-dephosphorising on the one hand, and the retentive and irretentive on the other. For reasons which are given, silicates and phosphates of iron are considered to be more dephosphorising for like basicity than those of lime. Besides the ordinary thermal and chemical reactions which occur, mass action is likely to have an important effect of a selective nature, which may vary according to attendant circumstances. Oxidising follows much the same course as in the open-hearth furnace, except that the fear of over-oxidising, ever present in that process, does not exist in electric

\* *Engineering and Mining Journal*, vol. lxxxviii. pp. 400-406.



smelting, as the subsequent deoxidising period is accompanied by deoxidising conditions so strong that over-oxidisation can be undone to practically any extent. It is, however, in the deoxidising and desulphurising stage that the chief interest lies, as the formation of calcium sulphide introduces something of a new departure into steel metallurgy, and enables desulphurisation to be carried much further forward than has hitherto been possible. If there has been an oxidising stage, the first step is to remove the phosphoric slag with great care, upon which rough deoxidisation can be brought about in the usual way by additions of carbon, silicon, manganese or aluminium, the carbon being used first, and the more expensive materials later. Coussergues seems to think carbon intrinsically unable to finish the deoxidising, and instances the oxygen remaining in metal made by the Darby process, notwithstanding the direct contact with solid carbon. The brief contact in the Darby process being insufficient completely to deoxidise does not, however, prove that prolonged contact, as in the electric furnace, would be incompetent to remove the whole of the carbon. In the Kjellin furnace this cannot perhaps be done, but in the Röchling-Rodenhauser process it can be achieved. The problem of desulphurising is then dealt with in detail, and the question whether extreme basicity is necessary in this operation is answered in the negative, although the importance of a requisite degree of basicity is fully recognised. The influence of manganese and of the temperature of working are then discussed, the final conclusions being as follows:—

As an instrument for melting and dephosphorising, the electric furnace has no advantage over the cupola and open-hearth furnace; certainly none that can compensate for the great loss of heat. It is the thorough deoxidising and consequent thorough desulphurising, and the removal of suspended matter and probably of hydrogen, that confer on the electric furnace the advantage. A large part of the superiority of electric steel may be referred to its greater freedom from oxide and suspended slag, and also perhaps from hydrogen and nitrogen. Whatever the elements of superiority may be, they are almost certainly the direct or indirect result of the strong deoxidising conditions in the deoxidising and desulphurising part of the process, or, in short, due to the freedom of the atmosphere of the electric furnace from oxygen.

The metallurgical aspects of the production of steel in the electric furnace are considered by E. R. Eichhoff,\* who points out that steel, saturated with a certain gas, may stand for hours without changing its gas contents in the least, provided the temperature remains the same. The deoxidation of the bath is the important point, and as the entry of the oxygen in the gas is due to the intervention of the protoxides of the slag, the latter must be removed, and the point to aim at is to keep the slags free from iron. By using fine coal on the slag in the

\* Paper read before the Verein zur Beförderung des Gewerbflusses, Berlin; *Iron Age*, vol. lxxxiv. p. 388.

furnace such slags can be produced, in the basic process, without carbonising the bath. A trial having shown that calcium carbide did not carburise the bath, despite previous assumptions, it was used as a reducing agent, but proved too expensive owing to the volume of slags. This was reduced, and it was believed that all further difficulties had been overcome, since there were available a hearth which did not affect the steel, and a cover of slag which not only did not influence it, but protected it from atmospheric effects. It was discovered, however, that the steel still contained as much oxygen as before, and further experiments and observations led to the assumption that oxygen combines in some form with iron, at temperatures higher than its point of fusion, and that the quantity increases with the temperature. In this form it cannot be attacked by carbon, but when the temperature declines below that corresponding to the point of saturation, oxygen may possibly be expelled in the form of protoxide of iron, and this combines at once with the carbon of the carbide, forming carbonic oxide. In endeavouring to apply these assumptions to the deoxidation of the steel below the slag freed from iron, it was found that oxygen could only be expelled where the temperature was lowered close to the point of chilling, and re-heating followed under the iron-free slag. This process being found to work too slowly, a special addition of carbon was made to hasten the reaction, and was combined with a duplex process. In this the entire oxidising process was consigned to the ordinary furnaces, the dephosphorised material being transferred to the electric furnace, where the greater part of the oxygen was removed by carbon, and the process carried to a close in the manner indicated. For carburising, a mixture of 50 per cent. of carbon and 50 per cent. of iron, called carburite, is used. This is so solid that it withstands the mechanical action of the slag, and is heavy enough to sink through it.

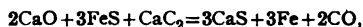
C. A. Keller,\* in dealing with the electric steel process, describes a conducting non-carbon hearth, compares series and parallel connection of the upper electrodes, and summarises his experience with the series system. The 8 to 10-ton furnace installed in 1905 at the Unieux Steelworks of J. Holtzer & Co. (Loire, France) is also described, and particulars of working are given. The steel is made in an open-hearth furnace, poured into a ladle, and then immediately fed into the electric furnace. The refining may be carried to 0.01 per cent. of sulphur and 0.01 per cent. phosphorus; regular practice gives sulphur, and phosphorus 0.015 to 0.02 per cent. The period of treatment varies, of course, with the quality of steel desired, and as an example of regular practice the following results are quoted: Weight of charge put into electric furnace, 7500 kilogrammes; mean power during operation, 750 kilowatts; period of working, 2½ hours. Composition of molten charge: carbon, 0.15 per cent.; sulphur, 0.06 per cent.; phosphorus, 0.007 per cent.; carbon content

\* Paper read before the American Electrochemical Society, May 6, 1909; *Electrochemical and Metallurgical Industry*, vol. vii. pp. 255-259.

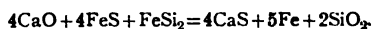
sought, 0.45 to 0.50 per cent. Analysis of product: carbon, 0.443 per cent.; sulphur, 0.009 per cent.; phosphorus, 0.008 per cent.; energy consumed per ton, 375 kilowatt hours. Electrode consumption, 18 millimetres per hour for four electrodes, having a cross-section of  $400 \times 400$  millimetres. For continuous working, and assuming the cost of electrodes to be 35 francs per 100 kilogrammes, this corresponds to a cost of about 4 francs per ton of steel. The labour on the furnace, including feeding of the necessary materials, was provided by three labourers and one melter. Illustrations are given of the Keller furnace plant.

F. A. Kjellin \* gives a full account of the development of the Kjellin and Röchling-Rodenhauser electric furnaces, and details the methods of working of induction and combination furnaces. With regard to the Röchling-Rodenhauser combination furnace, which was specially invented to refine molten steel from the Bessemer converter, the operation is as follows:—After tapping, fluid steel from the converters is poured into the furnace, and suitable materials—burned limestone and mill scale for forming a dephosphorising slag—are added. When the phosphorus is removed the carbon in the steel (if carbon steel is made) is adjusted by adding pure carbon to the bath, and afterward a new basic slag is formed in order to remove the sulphur. One necessary condition for successful desulphurisation is that the slag be free from iron, and therefore ferro-silicon is sometimes added in order to quicken the reduction of the iron in the slag.

R. Amberg † contributes an article on the deoxidation and desulphurisation of steel in electric furnaces. Neither the Stassano nor the induction furnaces have any areas of such a pronounced high temperature as the Héroult or Girod furnaces have right below the arcs. The high temperature is of importance for two reasons. First, it increases the fluidity of the slag and of the steel bath, and therefore facilitates diffusion and convection currents, and consequently the chemical reaction between slag and steel bath. Secondly, the high temperatures cause a very high reaction velocity; at low temperatures an increase of  $10^{\circ}$  C. generally doubles the reaction velocity, and at the temperature of the steel bath in the electric furnace the reaction velocity is probably infinitely high. The empirical formulas of the reactions by which sulphur is removed are as follows. In the Héroult furnace:—



and in the Röchling-Rodenhauser furnace:—

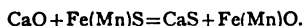


The reaction which underlies these two processes is the change of iron sulphide or manganese sulphide into calcium sulphide, and appears to lead to an equilibrium, which is displaced by a small

\* *Electrochemical and Metallurgical Industry*, vol. vii. pp. 265–266.

† *Ibid.*, pp. 115–116.

addition of metallic oxides towards the lime side (*i.e.* so that the reaction of the following equation when read from right to left is increased) :—



Hence a curve which would represent the desulphurisation as a function of the protoxide content in the slag does not show any sharp break, but a gradual bend when iron protoxide occurs. It may be mentioned that Osann's supposition of the reversal of the reaction  $\text{FeO} + \text{Mn} = \text{SFeS} + \text{MnO}$  for  $1350^\circ$  to  $1500^\circ$  has already been proved by E. Schütz \* to take place in fact.

W. Fielding † states that in the refining of steel in the electric furnace a very complete desulphurisation of the metal can be effected, and this action is found to be considerably facilitated by the addition of a charge of ferro-silicon. The reaction between ferro-silicon and ferrous sulphide was investigated by heating intimate mixtures of these compounds in a vacuum at known temperatures. The reacting substances were placed in a crucible in the form of a hollow graphite rod, which could be evenly heated by the passage of an electric current. Electrical connection was made with the rod by fitting it in graphite plugs, which in turn were soldered into water-cooled brass tubes to which cables could be attached. The rod was surrounded by a water-jacketed Jena glass tube, for experiments in which the rod was heated below  $1500^\circ$ ; above this temperature a silica tube was employed. The apparatus was made air-tight by luting the ends of the tube with soft wax. Temperature readings were made by means of a Wanner optical pyrometer in those cases in which a glass tube was employed, and changes in pressure were indicated by a mercury gauge connected with the tube.

Desulphurisation of steel in electric furnaces is described by E. Fornander.‡

A. Stansfield § traces the main features in the development of the electric furnace, with special reference to the electro-metallurgy of iron and steel, and describes the furnaces of Acheson, Siemens, Moissan, Héroult, and Colby.

The management of electric induction furnaces and the process of refining steel in them are described.||

J. B. C. Kershaw ¶ describes, with illustrations, the various methods of refining steel in the electric furnace.

The report by the Committee appointed by the Norwegian Board of Trade to inquire into the electro-metallurgical production of iron and steel has been published.\*\*

\* *Metallurgie*, vol. iv. pp. 660-662.

† *Transactions of the Faraday Society*, vol. v. pp. 110-112.

‡ *Bihang till Jernkontorets Annaler*, 1909, pp. 291-296.

§ Paper read before the Canadian Mining Institute, March 3, 1909.

|| *Iron and Steel Times*, vol. i. pp. 450-452, 462-463.

¶ *Cassier's Magazine*, vol. xxxvi. pp. 237-249.

\*\* *Iron and Coal Trades Review*, vol. lxxix. pp. 548, 577-578.

**Lash Process in the Electric Furnace.**—F. A. J. FitzGerald \* explains the way in which the Lash process can be applied to the electric furnace. Hundreds of tons of steel, it is stated, have been made in the open-hearth furnace, using the Lash process, and it has been shown by experience that a superior quality of steel is obtained in this way, and that the cost of production is in general lower than when the regular methods are employed. Various tables are given of the composition of the Lash mixture when used in the open-hearth and in the electric furnace, and in comparison with the ordinary open-hearth process. These tables are summed up in the following table, giving a comparison of different methods of producing 100 tons of steel ingots.

Raw Materials.	Open-hearth Furnace, Scrap and Pig.	Open-hearth Furnace, Pig and Ore.	Open-hearth Furnace, Lash Process.	Electric Furnace, Lash Process.
	Tons. 50	Tons. 94	Tons. 60·1	Tons. 40·7
Pig iron . . . .	57	...	...	...
Scrap . . . . .	2	26	75·2	103·0
Ore . . . . .	...	...	13·4	19·5
Coke . . . . .				

**The "pinch" Phenomenon in Electric Furnaces.**—C. Hering † deals with the working limit in electrical furnaces due to the "pinch" phenomenon. The pinch effect produces a pinch pressure which sucks the liquid from the centre and forces it out near the ends, thus producing a difference in level which is equivalent to a hydrostatic pressure. A condition of equilibrium is reached when this hydrostatic pressure just balances the pinch pressure. In the discussion which ensued, E. F. Northrup thought that the theoretical formulas in the paper would probably prove more reliable in their application to large furnaces than deductions from the small-scale experiments. F. A. J. FitzGerald mentioned that the largest scale on which he observed the pinch phenomenon was when an attempt was made to melt aluminium in a 60-kilowatt induction furnace, the depth of the channel being 6 or 7 inches, and the width 2 inches. Successful melting in this case was prevented by the pinch phenomenon.

**Electric Steel Furnaces of Special Type.**—G. Gin ‡ gives an account of an improved form of induction furnace constructed for the

\* Paper read before the American Electrochemical Society, May 6 to 8; *Electrochemical and Metallurgical Industry*, vol. vii. p. 268.

† *Ibid.*, p. 266.

‡ *Transactions of the Faraday Society*, vol. v. pp. 137-158.

Krupp works at Essen. The furnace consists of two crucibles of unequal size, the larger of which is the working crucible, and is fitted with a door for drawing off the slag and a pouring spout for the finished steel. The crucibles are connected by inclined channels placed wholly below the level of the molten material, through which a continual circulation of the metal takes place. By this means the heating is kept uniform throughout the furnace. Every portion of the molten mass comes successively and rapidly into contact with the oxidising slag. The dimensions and gradient of the channels are so designed that a minimum velocity of 0.40 metres per second is obtained. The furnace has a capacity of 5 tons, and requires 420 kilowatts at a primary pressure of 4800 volts and a frequency of 5. The principle can also be applied to furnaces of the arc type. The construction of the furnace is fully illustrated.

An illustrated description is given by P. Girod \* of his electric steel furnace, with data taken from Girod furnaces in actual operation at Ugine, in the works of the Compagnie des Forges et Acières Électriques Paul Girod. A review of the various Girod furnaces in commercial operation is given with tables of the different steels made at the Girod works. They range from extra soft to hard (0.08 to 0.6 carbon), the sulphur being from 0.010 to 0.017 per cent., and the phosphorus from 0.005 to 0.012 per cent.; also five grades of nickel steel and nickel-chromium steel, the composition of the latter being 0.420 carbon, 0.199 silicon, 0.500 manganese, 0.010 sulphur, 0.009 phosphorus, 0.77 chromium, and 2.53 nickel.

J. A. Seager † deals with the manufacture of steel in the Girod electric furnace, a description of which is given.

A. Grönwall ‡ describes a new electric steel furnace constructed by A. Lindblad. It is an electrode furnace, and either two-phase or three-phase alternating current can be used. A circulation in a vertical direction is set up within the molten metal, facilitating the refining by more intimate contact with the slag.

An illustrated description of the Grönwall electric steel furnace is given elsewhere.§

R. Turnbull || discusses the Héroult electric steel furnace, and gives illustrations of the 15-ton furnace installed at South Chicago. The main points claimed for the Héroult furnace are specified, and examples from practice at La Praz of the refining possibilities of the furnace are given. It is stated that the number of kilowatt-hours necessary in the Héroult furnace to melt and partially refine 1 ton of steel is 600, 100 more being necessary for the finishing slag, making 700 in all. These figures are for a 5-ton furnace, and starting

\* Paper read before the American Electrochemical Society, May 6 to 8, 1909; *Electrochemical and Metallurgical Industry*, vol. vii. pp. 259-260.

† *Iron Trade Review*, vol. xlv. pp. 1027-1029.

‡ *Bihang till Jernkontorets Annaler*, 1909, pp. 409-413.

§ *Iron and Coal Trades Review*, vol. lxxviii. p. 817.

|| Paper read before the American Electrochemical Society, May 6 to 8, 1909; *Electrochemical and Metallurgical Industry*, vol. vii. pp. 260-262.

on cold scrap; in the case of a 15-ton furnace they would be considerably reduced. Should molten metal be charged into the furnace, and no other work be demanded besides the recarburising, desulphurising, and deoxidation of the steel, from 140 to 160 kilowatt hours are necessary in the 5-ton furnace; for a 15-ton furnace this will probably be cut down to 100 kilowatt hours.

C. A. Hansen \* describes, with illustrations, a small experimental Héroult furnace with which over 200 charges have already been made of very soft steels, high-speed tool steels, chromium steels, manganese steels, and a variety of special alloys, the charges varying from as little as 50 lbs. to 300 lbs., with very satisfactory results. Particulars are given as to power consumption, metal losses, slags, &c., and the following list of analyses represents the results of twelve consecutive charges of alloy steel in which the mixture consisted chiefly of sheet scrap, averaging :—

	Per Cent.
Carbon . . . . .	0·2
Sulphur . . . . .	0·05 to 0·06
Phosphorus . . . . .	0·05
Silicon . . . . .	0·10
Manganese . . . . .	0·35

In general, slag was removed once and a second slag added.

	Carbon.	Phosphorus.	Silicon.	Manganese.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
1. . . . .	0·13	0·052	0·014	0·140
2. . . . .	...	0·019	0·010	0·076
3. . . . .	...	0·024	trace	0·082
4. . . . .	0·082	0·022	0·012	trace
5. . . . .	0·067	0·021	0·012	0·053
6. . . . .	0·098	0·014	0·010	0·140
7. . . . .	0·125	0·021	0·026	0·076
8. . . . .	0·071	0·030	0·026	0·079
9. . . . .	0·129	0·044	0·007	0·076
10. . . . .	0·094	0·026	0·008	0·086
11. . . . .	0·130	0·041	0·013	0·112
12. . . . .	0·088	0·029	0·013	trace

C. A. Keller † describes a type of electric steel-refining furnace in which a conducting hearth, consisting of non-carburising material, forms one of the electrodes. In the present case the hearth consists of reinforced clay made up on iron bars 25 to 30 millimetres in diameter placed vertically about 25 millimetres apart and packed solid with magnesia. When hot the whole hearth is conductive and the electrical resistance is very small. The furnace requires careful design to minimise self-induction and increase the power factor. With a fre-

\* *Electrochemical and Metallurgical Industry*, vol. vii. pp. 206-208.

† *Transactions of the Faraday Society*, vol. v. pp. 113-136.

quency of 20 a power factor of 0·9 should be obtained with a furnace of 1000 kilowatts.

The development of the electric furnace is dealt with, and an illustrated description of the Kjellin type is given.\*

E. Stassano † reviews the evolution of the design of arc, resistance, and induction furnaces, and gives an illustrated description of the Stassano steel furnace.

An illustrated description has appeared ‡ of the Tone electric reduction furnace for smelting refractory ores.

J. M. Stansbie § discusses the employment of high temperatures in the metallurgy of iron, and describes the arc, the resistance, and the induction types of electric furnace in detail.

**Efficiency of Induction Furnaces.**—J. Härdén || states that a 60 kilowatt furnace has an average efficiency of 40 to 50 per cent., that of a 125 kilowatt furnace being over 70 per cent., owing to the possibility of treating a greater quantity of metal in a shorter time. Records taken over several months show that ordinary tool steel requires about 650 kilowatt hours per metric ton, whilst the highest grade may require 750 to 800 kilowatt hours in a furnace of 1·5 to 2 tons capacity. Taking the cost of power at £3, 15s. per kilowatt year, these figures work out at 5s. 5d. and 6s. 8d. respectively for melting 1 metric ton of tool steel, and including all possible losses it should not cost more than 8s. 4d. per ton. The chief source of loss is heat radiation, while the electrical and magnetic losses together amount to 5·5 to 6·5 per cent. of the total energy.

In an article on induction furnaces ¶ details are given of the construction of the simple induction furnace as in the case of the Kjellin furnace, and similar details with illustrations are given of the "combination furnace" invented by Rodenhauser, a combination of the induction principle with electrodes. The combination furnace is intended for cases where an efficient refining operation is required, and is constructed in such a way that slags are easily worked in a roomy and accessible central hearth. Hot metal taken from the converter, open-hearth furnace, or gas-fired mixer can be treated, and the furnace is particularly adapted for treating and producing steel in large quantities, the metallurgical reactions being similar to those in open-hearth practice. The following data are given in connection with power consumption, &c., of simple induction and combination furnaces of various sizes :—

\* *Iron and Steel Times*, vol. i. pp. 310-312.

† Paper read before the American Electrochemical Society, May 6, 1909; *Electrochemical and Metallurgical Industry*, vol. vii. pp. 254-255.

‡ *Engineering and Mining Journal*, vol. lxxxviii. p. 313.

§ Paper read before the Birmingham Branch of the British Foundrymen's Association, April 24, 1909; *Ironmonger*, vol. cxxvii. p. 219.

|| *Electrochemical and Metallurgical Industry*, vol. vii. pp. 320-322.

¶ *Ibid.*, pp. 171-172.



Capacity in Tons.	Maximum Power in Kilowatts.	Power to keep Furnace hot.	Power Factor per Cent.	Periods.
0·1 to 0·15, simple induction . . . . .	60	25	0·76	60
0·5 to 0·75, combination . . . . .	100	30	0·85	50
0·8, simple induction . . . . .	150	40	0·70	25
1·0, combination . . . . .	175	50	0·80	50
1·5, combination . . . . .	275	80	0·70	50
1·6, simple induction . . . . .	225	75	0·65	16
2·5, simple induction . . . . .	350	310	0·58	14
3·0, combination . . . . .	350	100	0·60	50
3·0 to 3·5, combination . . . . .	350	100	0·80	25
5·0, combination . . . . .	550	165	0·65	25
7·0, combination . . . . .	700	210	0·60	25

The 7-ton combination furnace is claimed to produce daily 140 tons of rail steel and 63 tons of high-grade steel.

T. Rowlands \* gives the results of experiments carried out at the works of the American Furnace Company, to show the possibilities of the electric furnace.

**Electro-Steel Rails.**—F. A. Kjellin † deals with the production of steel for rails in the electric furnace. For some time the Prussian State Railways have used rails made from steel prepared in a Röchling-Rodenhauser furnace, and in accordance with the following specifications. Tensile strength for track rails, a minimum of 70 kilogrammes per square millimetre, or about 99,000 lbs. per square inch. For point or switch rails, 75 kilogrammes per square millimetre, or about 106,000 lbs. per square inch.

**Electro-Steel for Structural Purposes.**—H. D. Hibbard ‡ compares, from a business standpoint, the value of electric steel for structural work with that of steel made by the Bessemer and open-hearth processes.

\* *Canadian Machinery*, May 1909, pp. 38-40.

† Paper read before the American Electrochemical Society, May 1909; *Electrochemical and Metallurgical Industry*, vol. vii. pp. 265-266.

‡ *Ibid.*, vol. viii. p. 269.

## FURTHER TREATMENT OF IRON AND STEEL.

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**Case-Hardening.**—G. Charpy\* discusses the case-hardening of iron and its alloys by carbon monoxide, and a series of experiments have been carried out to ascertain the action of the gas on the metal and the mode in which it operates. The experiments consisted in heating iron at different temperatures in a current of pure carbon monoxide. The metal, which was generally employed in the form of wire varying in diameter from 0.3 millimetre to 0.5 millimetre, was placed in magnesia boats in the interior of a porcelain tube heated by an electric resistance furnace of platinum, a Le Chatelier pyrometer registering the temperature and allowing of its regulation at varying heights. Current at practically constant strength was furnished by a battery of accumulators, so that for some of the experiments it was possible to allow the apparatus to work throughout the night without fear of any considerable variation in temperature. The carbon monoxide was prepared by the action of sulphuric acid on ferrocyanide of potassium, and absorbed by a hydrochloric acid solution of cuprous chloride. The latter solution was then heated, and the evolved gas stored in large flasks which served as gasometers. The gas before being used was passed through a tube heated in an electric furnace and containing metallic copper in order to remove the traces of oxygen that it might have retained, and then through tubes containing nitrate of silver, soda lime, and pumice-stone moistened with sulphuric acid. On issuing from the tube containing the metal subjected to experiment the gas was again passed through tubes containing soda lime, and the variations in weight were noted in each experiment. It was also passed over pumice-stone saturated with sulphuric acid and finally collected in flasks, where it was stored for subsequent experiments. In each experiment there were ascertained (1) the weight of carbon dioxide formed; (2) the increase in the weight of the metal; and (3) the carbon contained in the metal. The latter was determined by burning the metal in oxygen, the previous determination of the carbon enabling the increased amount absorbed during the experiment to be estimated. In these circumstances it

\* *Revue de Métallurgie, Mémoires*, vol. vi. pp. 505-518.

was found that above a temperature of  $850^{\circ}$  to  $900^{\circ}$  the dissociation of the carbon monoxide was not accompanied by a deposition of any appreciable quantity of carbon. The three methods of determination give practically concordant results. At lower temperatures the iron was covered with a layer of pulverulent carbon which could easily be separated from the wire. The absorbed carbon was estimated on samples from which this layer of carbon had been removed. Tables showing the results are given. The metal experimented upon was a piano wire containing 0.04 per cent. of carbon; dead soft open-hearth steel containing 0.09 per cent. of carbon, 0.25 per cent. of manganese, 0.015 per cent. of phosphorus, 0.1 per cent. of sulphur and traces of silicon; and fine turnings of dead soft steel containing 0.07 per cent. of carbon, 0.30 per cent. of manganese, 0.20 per cent. of phosphorus, and 0.015 per cent. of sulphur. Although in the circumstances described the rate of cementation does not appear appreciably to increase with the temperature from  $900^{\circ}$  upwards, the case-hardening has no definite demarcation, but continues indefinitely with the formation of graphite as long as the action of the gas is continued.

A further series of experiments was carried out on chromium, manganese, and nickel, with the object of ascertaining whether the presence of certain elements in the steel would modify the case-hardening action of carbon monoxide. By heating pure finely powdered chromium in a current of carbon monoxide at a temperature of  $1000^{\circ}$  no evolution of carbon dioxide was found to occur. The gas was wholly absorbed; rapidly at first, and afterwards more slowly, with the production of a blackish substance amidst which could easily be distinguished green grains of chromium oxide intermingled with carbon. A similar action was found to occur when chromium, obtained by aluminothermy and containing 97 per cent. of chromium and 3 per cent. of aluminium was used. The pure manganese, heated at  $1000^{\circ}$  in carbon dioxide, similarly absorbed the gas without evolution of carbon dioxide. After two hours' heating the turnings had increased 26.62 per cent., and contained 9.06 per cent. of carbon and 12 per cent. of oxygen. In an experiment which was prolonged for twenty-eight hours at the same temperature the transformation was complete, the resulting product being a mixture of manganese protoxide and carbon. In the case of nickel there was but a slight degree of carburisation, insignificant in comparison with the action on iron. With a view to ascertaining whether these modes of action were reproduced in the case of special steels, ordinary commercial chromium steel and chromium nickel steel were experimented upon, and the results are tabulated.

The theory of the action of carbon monoxide in case-hardening is then discussed. In order to elucidate some obscure points experiments were undertaken to ascertain what action cyanides might play, and also the results that might be obtained by case-hardening in an atmosphere devoid of nitrogen. The experiment appeared to indicate that the presence of cyanides was not necessary in case-hardening, and that the case-hardening is produced chiefly by

the gases evolved by the case-hardening agents. The ultimate conclusions arrived at as the result of the research are as follows: The carbon monoxide, heated in contact with iron, decomposes with the formation of carbon dioxide and the cementation of the iron. This carburising action of carbon monoxide appears to play an important part in case-hardening carried out by means of solid case-hardening agents with a carbon basis, the action of which may be explained by this means without having recourse to any theory as to the formation of cyanide, the existence of which has indeed never been up to now definitely proved. The want of harmony in earlier experiments relating to case-hardening may easily be explained if there be taken into account (1) the lack of means of measuring high temperatures; (2) the ignorance respecting the laws of chemical equilibrium, and, in particular, of the dissociation of carbon monoxide at moderately high temperatures; and (3) the inadequacy of the methods employed to ascertain case-hardening, which cannot be defined in terms of carbon percentages. From a commercial point of view the bearing is important. With any case-hardening material it is possible, by properly graduating the temperature and duration of the heating, to obtain a dissemination of carbon of almost any extent, the solution of the problem in any particular instance being a matter of time and patience only. What, however, requires elucidation is the most suitable distribution of carbon required for specific cases. What, for instance, should be the thickness of the case-hardening layer, and what the percentage of carbon in order that the manufactured piece shall behave well?

J. C. Olsen \* and J. S. Weiffenback describe experiments on the case-hardening of steel by gases, in order to ascertain the relative efficiencies of the various carbon gases, and also the chemical reactions that take place when the carbon from a given gas enters the steel. The three gases studied were, in the order of their carburising ability, carbon monoxide, acetylene, and methane. Carbon monoxide is found to be the best gas for the purpose, as no ammonia is necessary, and it gives the best penetration in a given time.

**Annealing Furnaces.**—C. M. Ripley † gives an illustrated description of an internally fired helical furnace for annealing or hardening purposes. Either oil or gas may be used as fuel, and it is injected directly into the chamber in the opposite direction to that of the travel of the material. Combustion is complete, and the spent gases find vent where the material enters, thus utilising the heat to the fullest extent. Such heating is the correct method, especially for hardening steel which should enter the bath at its rising hardening temperature. This action is important also in preventing or reducing oxidation. Either air or dry steam may be used to inject the

\* *Transactions of the American Institute of Chemical Engineers; Iron Age*, vol. lxxxiv. pp. 120-121.

† *Electrochemical and Metallurgical Industry*, vol. vii. pp. 130-131.

oil or gas fuel. Coal or coke fuel cannot be used. One of the chief features of the internally fired helical furnace is its durability. Practically all the ironwork is out of range of the fire, and all the parts are simple and strong.

An illustrated description is given \* of the Vaughan-Hughes furnace for the heat treatment of metals.

G. P. Blakiston † describes an oil-fired furnace for annealing or tempering steel.

Electrically heated annealing furnaces are described by A. Kjör-ling. ‡

C. U. Scott § gives a description of coal- and gas-fired, barium chloride, lead pot, muffle, oven and oil tempering furnaces and methods of hardening, annealing, and tempering.

It is stated || that in gas pile-heating not only is there a great economy in fuel, but, what is of still more importance, there is a reduction in the loss of oxidation in the furnace of at least  $2\frac{1}{2}$  per cent. This saving represents about £825 per annum, taking as an example a furnace heating about 20 tons of iron piles per shift and the value of the normal loss of iron lost by oxidation per shift. With gas-fired furnaces, as compared with direct coal-fired furnaces, there is usually a saving in the cost of repairs of about 2d. per ton of iron heated.

**Tempering and Hardening of Steel.**—C. M. Johnson ¶ gives the results of his experience of the proper temperatures at which various tool steels should be annealed. The author has also carried out experiments on the formation of graphitic carbon in cold rolled steel. This he considers to be due entirely to the annealing to which the steel is subjected, the annealing being conducted within such a range of temperature that the combined carbon breaks down. Three different lots of cold rolled steel were subjected to prolonged annealing, and by means of analyses the formation of the graphitic carbon was noted.

O. M. Becker \*\* discusses methods of tempering high-speed steel. A method involving the use of a metal sand-pan heated by a suitable gas- or oil-burner is recommended as giving fairly accurate results when the temperature is carefully controlled by frequent observations of the pyrometer. Where the tools to be tempered are small, a method that consists of heating the tools in baths which melt at pre-determined temperatures can be employed. One disadvantage that limits the usefulness of this method is the impossibility of varying the temperature of the bath without keeping in stock a large number of alloys. A table is given showing a list of alloys and the temperatures

\* *Iron and Coal Trades Review*, vol. lxxix. pp. 350-351.

† *Iron Trade Review*, vol. xlv. p. 36.

‡ *Teknisk Tidskrift (Afdelningen för Mekanik)*, vol. xxix. pp. 65-68.

§ *American Machinist*, vol. xxxii. Part I. pp. 694-697.

|| *Iron and Steel Times*, vol. i. p. 306.

¶ *Iron Age*, vol. lxxxiii. p. 1301.

\*\* *American Machinist*, vol. xxxii. Part I. pp. 573-574, 660-661.

near which they melt, with the colour of the steel at those temperatures. Tempering with oil and electricity is also dealt with.

H. C. H. Carpenter \* discusses the hardening of high-speed steels. He states that their composition varies greatly. They consist of an alloy of iron with anything between 0·5 per cent. and 1 per cent. of carbon, 12 to 19 per cent. of tungsten, 3 and 6 per cent. of chromium, and often a little vanadium. He contests the theory put forward by Osmond and Böhler to account for the hardness of tool steel.

J. Weaner † gives the following method for making a compound for use in hardening steel tools: 2 lbs. of rye meal, 1 lb. of common salt,  $\frac{1}{4}$  lb. of pulverised charcoal,  $\frac{1}{4}$  lb. of pulverised borax,  $\frac{1}{4}$  lb., or one-third of a pint, of liquid cyanide of potassium, half a gill, or 2 oz., of water glass (silicate of soda), and three pints of water. The liquid cyanide is made by dissolving 3 oz. of pulverised potassium cyanide in one pint of boiling water. After these ingredients are mixed thoroughly to form a paste, the steel is heated to cherry redness, rolled in the paste, and then dipped in a bath of either sperm, fish, or kerosene oil.

E. T. Clamage ‡ discusses English and American high-speed steels, and explains the hardening of such steels.

A description is given § of a plant erected in America, which is devoted exclusively to the heat treatment of steel. All grades of steel from the 0·15 per cent. carbon steel to high speed, alloy, air- and water-hardening steels may be conveniently and efficiently handled and treated.

Recent improvements in the manufacture of high-speed tool steel are described. ||

J. Cran, ¶ in discussing methods of gauging heats for hardening carbon steel, states that as steel at the point of recalescence loses its magnetic properties, this point can be determined by the use of a magnetic needle. The work to be hardened is heated as uniformly as possible until it approaches cherry heat or dark red when it is tried by moving it backward and forward on a plane with the needle. If the needle remains perfectly still, the steel, having lost its magnetic properties, has reached the point of recalescence, and is in the right condition to be quenched for the best results. A method of heating with a forge fire is also described.

E. W. Harris \*\* considers that there is sufficient definite knowledge on the subject of hardening steel to warrant a systematic tabulation of facts with methods of applying them, and gives suggestions for the lines upon which such a system might be drawn up.

**Heat Treatment of Steel.**—W. T. Koken, †† W. Campbell, and H. M. Howe have investigated the problem as to whether the tem-

\* Paper read before the Birmingham Metallurgical Society; *Ironmonger*, vol. cxxvii. p. 353.

† *American Machinist*, vol. xxxii. Part I. p. 919.

‡ *Machinery*, vol. xv. pp. 633-634.

¶ *American Machinist*, vol. xxxii. Part I. pp. 568-569.

‡ *Ibid.*, pp. 1031-1032.

|| *Ibid.*, pp. 622-623.

\*\* *Ibid.*, p. 899.

†† *Proceedings of the American Society for Testing Materials*, vol. viii.; *Iron Age*, vol. lxxxviii. p. 1859.

perature that is correct for refining the coarse structure of overheated steel is also suitable for removing that of unannealed steel castings (ingotism). A series of tests was made, comprising one piece of an untreated casting, one piece of a treated casting, and one piece of treated rolled steel. Each set was heated to a definite high temperature and then either cooled immediately after reaching it, or else kept thereat for a considerable time, and then slowly cooled. The first heatings were carried out in a gas-forge and the second in a Sauveur muffle, heated internally by the resistance of a coil of platinum wire. The temperatures were controlled by means of a Le Chatelier pyrometer. The results, which are given, have led to the following conclusions: (1) The lower therapeutic temperature, at which there is rapid effacing of the coarse network ferrite caused by overheating at  $1377^{\circ}\text{C.}$ , is between  $804$  and  $840^{\circ}\text{C.}$ , and hence probably above  $A_{c_3}$ . (2) Ingotism is not cured in this steel, even by an exposure of thirty-two hours to this temperature. (3) The upper therapeutic temperature, at which ingotism is cured in this steel, is between  $1180$  and  $1194^{\circ}\text{C.}$  (4) The lower therapeutic temperature of the de-ingotised steel casting is substantially that of overheated rolled steel of like composition. (5) The critical temperatures in the initial heating of an annealed steel casting are the same as those of the same casting after de-ingotising.

E. Maurer\* describes the results of researches on the heat treatment of iron and steel. The variations, caused by quenching, in the physical properties of pure iron are referred to deformed  $\alpha$ -iron. Homogeneous austenite can be obtained by quenching in the same manner as the mixture austenite-martensite if a sufficient quantity of manganese is added. The critical temperature depends on the percentage of manganese. On tempering steels containing a small percentage of manganese between  $150$  and  $125^{\circ}\text{C.}$  austenite transforms into troostite. In the mixture austenite-martensite martensite begins first to transform, but the transformation takes place more slowly. As opposed to the phenomena observed in tempering, austenite on cooling transforms in martensite. Cold hardening has the same action as positive quenching, although in a far smaller degree. In principle there is no difference between the curves of tempered iron and cold-hardened steel. The influences brought into play by quenching must depend on at least two causes, one of which, the hardening carbon, brings about the variation of electrical conductivity, while the other brings about the variation of magnetism, hardness, and density.

J. S. Unger† discusses the heat treatment of special steels. In order to develop the best qualities of any special alloy it is necessary not only to anneal it, but to submit it to a more or less complicated treatment, depending on the results required. The effect of treatment is specially noticeable in manganese steel castings. It is a

\* *Metallurgie*, vol. vi. pp. 33-52.

† *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xxv. pp. 338-342.

common and necessary practice amongst those who manufacture manganese steel to heat the article to approximately  $950^{\circ}$ , plunge it into cold water, and leave it until it is absolutely cold. This develops the characteristic toughness and increases the hardness to a higher extent than they were prior to treatment. The methods of breaking up a coarse structure are described.

L. H. Fry \* describes a series of tests made to determine the effect of heat treatment on the transverse elastic limit and modulus of elasticity of spring steel.

L. Guillet † deals with the heat treatment of steel products.

F. George ‡ discusses the temperature to which steel can be heated above the recalescence point without injury, and deals with tests made with steels containing respectively 0.35, 1.00, 1.25, 1.35, 1.50, and 1.65 per cent. of carbon.

A. Campion § states that steel of axle quality appears to be brought to the best condition for resisting sudden shock or continued vibration after heating to temperatures between  $700$  to  $800^{\circ}$  C., followed by a moderately slow cooling. If this class of material is heated to  $900^{\circ}$  C. or higher, very pronounced brittleness is produced. Slow and prolonged cooling between  $600$  and  $500^{\circ}$  C. does not appear to be specially harmful to this grade of material.

The report of the Committee on Heat Treatment of Steel appointed by the American Society for Testing Materials, dealing with suggested specifications for annealing, has been published.||

A description of the Bernardos process of welding by the electric arc is published.¶ The method followed is that of making the piece itself the positive pole of the arc, the negative being a stick of hard carbon. Either accumulators or a direct-current dynamo, or the two together, may be used to produce the necessary current. The generator or cells having been connected up, the carbon rod is moved backwards and forwards over the joint to be welded, the intense heat of the arc rendering the metal fluid in a few seconds. Examples of welding are given, and the advantages of the process are enumerated.

C. B. Auel \*\* deals with arc welding, and briefly describes the process of electric welding by Thomson, Zerener, La Grange-Hoho, and Bernardos.

V. D. Green, †† dealing with this subject, describes the various types of Thomson electric welders, enumerating their advantages, and discussing the voltage required for a successful plant.

\* *Page's Weekly*, vol. xv. pp. 777-779.

† Paper read before the Seventh International Congress of Applied Chemistry, London.

‡ *American Machinist*, vol. xxxii. Part I. pp. 938-939.

§ *Iron and Steel Times*, vol. i. pp. 157-166.

|| *Iron Age*, vol. lxxiv. p. 97.

¶ *University of Birmingham Engineering and Mining Journal*, vol. vii. pp. 330-345.

\*\* *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xxv. pp. 213-244.

†† Paper read before the Birmingham and District Electric Club, April 17, 1909; *Engineer*, vol. cvii. p. 386.



W. F. Fischer \* deals with the welding of pipe work for superheated steam, and describes the Zerner, Bernados, Voltex, Thomson, oxy-acetylene, oxhydrogen, and thermit welding processes.

W. I. Reich † gives the results of some tests made on oxy-acetylene welded joints, and enumerates the conclusions that can be drawn from the data obtained.

H. Cave ‡ describes a method of repairing cylinders by means of the oxy-acetylene flame.

The physical aspects of welding are dealt with § from a technical point of view, and comparisons are made with regard to the oxy-acetylene, oxy-hydrogen, and electric systems of welding.

A. Davis || deals with autogenous welding.

J. Knappich ¶ discusses the most suitable fluxes for use in autogenous welding.

It is stated \*\* that the increased application of the oxy-acetylene process for welding and cutting metals has caused the Deutsche Azetylenverein to form a special group for the study of the autogenous welding of metals.

Particulars are given †† of the process of cutting iron and steel plates by means of a blowpipe. Either coal-gas, acetylene, or hydrogen may be used in combination with the oxygen, the former being the best for new and clean metal. The process is specially convenient for making circular cuts, and by increasing the size of the cutter it can be used for plates exceeding even 12 inches in thickness. It can be employed to great advantage in removing old material from confined situations.

Another illustrated description of the process of metal cutting by oxygen, and of the apparatus used for this purpose, is given elsewhere. ‡‡

**Steel Rails.**—The Pennsylvania Steel Company has been working on the problem of rolling manganese steel rails in view of the high cost of cast manganese rails. The company has now produced a rolled rail made of "Manard" steel, a manganese steel which has been extensively used for crusher jaws, coal-breaker rolls, and particularly for crossings, frogs, and switches for railways. The difficulties attending the rolling of manganese steel on a commercial scale were considerable, the metal being extremely hard at the proper rolling temperature. Examples are given illustrating toughness, ductility, and resistance to shock possessed by the Manard rail. A machine for testing the wear of rails is also described. §§

J. E. York ||| discusses the improvement of the physical properties

\* *Power*, vol. xxxi. pp. 518-524.

† *American Machinist*, vol. xxxii. Part I. pp. 686-687.

‡ *Machinery*, vol. xv. pp. 591-592.

§ *Electrochemical and Metallurgical Industry*, vol. vii. pp. 226-228.

|| *Ibid.*, pp. 233-234.

\*\* *Giesserei Zeitung*, vol. vi. p. 181.

†† *Page's Weekly*, vol. xv. pp. 773-776.

‡‡ *Bulletin of the American Institute of Mining Engineers*, 1909, pp. 455-467.

¶ *Eisen Zeitung*, vol. xxx. pp. 473-474.

†† *Engineering*, vol. lxxxviii. pp. 168-170.

§§ *Iron Age*, vol. lxxxiii. pp. 1261-1262.

of steel rails. The means by which improvements in quality can be imparted, without any radical changes in the method of rolling, are furnished by registering the power consumption of electrically driven mills. The record in kilowatts of the power required to roll an ingot of a given size into a rail can be used to control the temperature at which to finish the rail. It is claimed that such a record will furnish a simple and reliable pyrometer, and its application promises many advantages. Sound ingots only should be employed in the rolling of steel rails, as it is impossible to get rid of piping or to remedy segregation by any rolling operations, and any process having that object in view must be applied before the ingots reach the mill.

The manufacture of steel rails at the works of the Lackawanna Steel Company, Buffalo, U.S.A., is described and illustrated.\*

P. Fischer † describes how the first grooved rails came to be rolled in 1879 by the Phoenix Company at Laar, near Ruhrort. By the aid of illustrations he traces the further development of tramway rail sections, and explains the principles which govern the choice of their forms. A table is given of the German and English patents bearing upon the subject.

**Rolling of Structural Steel.**—W. Tafel ‡ gives a description of some new methods for the calculation of the form and dimensions of the ingots to be worked down by a train of rolls, so that the finished product spreads to the full section of the last pass, this having hitherto been a matter of intuition formed and guided by practical experience. The author shows how the ingot expands or contracts in different directions, and how to predetermine such movement. The parts of the ingot should bear the same proportion to each other as the corresponding parts of the rolled section. This being only partly possible, the question arises how best to form a comparatively regular ingot which can be rolled into an irregular section with the least difficulty. The outside parts tend to travel faster than the interior. They are indeed held back by the others, so that the actual stretch is a mean between the stretches due to the compressions of the several parts, and a certain amount of internal strain is thereby set up between these. If an oblong-sectioned ingot be compressed at its sides, the thickness of the middle part decreases, while if the pressure be upon the middle strip the side strips decrease in thickness and break or fray out in saw-like fashion at the edges. The work of rolling has to overcome:—

1. The transverse pressing-out of the material from one part to another.
2. The stretching of the material in the longitudinal direction.
3. The distribution of the material from one part to another due to unequal longitudinal stretch.

\* *American Machinist*, vol. xxxii. Part I. pp. 679-685.

† *Stahl und Eisen*, vol. xxix. pp. 1217-1221, 1262-1267.

‡ *Ibid.*, pp. 649-663.

The general rule is suggested that the filling-out of the section takes place according to the order in which the sum of the resistances to these three processes is least. Results of experiments and tentative formulæ founded thereon are given.

**Straightening Girders.**—J. T. Browne\* discusses the straightening of steel girders, and describes a machine designed on the principle of a "Jim Crow." The machine is constructed in sizes for use on both light and heavy sections, being hand and power driven respectively. The cost of labour is claimed to be less than half that of straightening by any other means, and the machine, which may be fitted with wheels so that it may be moved from place to place if desired, will also deal with rails, angles, channels, and other sections.

**Steel Tubes.**—An illustrated description is given† of the various processes for drawing seamless tubes from solid steel billets.

G. Hess‡ describes a method of finishing small hardened steel tubes.

**Wire.**—A description is given§ of a model plant erected at Worcester, Massachusetts, for the manufacture of wire from charcoal iron.

**Forging Steel Car Wheels.**—J. H. Baker|| describes and illustrates his method of forging steel car wheels and the machinery designed for the purpose. The chief feature of this method is that it forges the blank for a wheel to a point where it is ready for rolling to a finish by a series of successively acting dies, of which each pair makes one impression, withdraws, and is followed by other pairs of dies increasing in diameter. The metal which has been shaped by a die is firmly held by another pair of dies automatically put into place, thus preventing the flowing back of the metal into that portion that has already been reduced to the proper thickness.

The manufacture of Schoen forged steel wheels is described.¶

**Forging Crank Shafts.**—E. F. Lake\*\* describes and illustrates the operations carried out in forging a 400-lb. crank shaft, and the machines, dies, and steel used. The temperature at which to forge steels is also dealt with.

\* Paper read before the Midland Counties Institution of Engineers, April 1909; *Colliery Guardian*, vol. xcvi. p. 875.

† *Canadian Machinery*, May 1909, pp. 43-46.

‡ *American Machinist*, vol. xxxii. Part II. pp. 163-164.

§ *Iron Age*, vol. lxxxiii. p. 2031.

|| *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xxv. pp. 165-190.

¶ *Iron Trade Review*, vol. xlv. pp. 1124-1127.

\*\* *American Machinist*, vol. xxxii. Part I. pp. 612-615.

**Chains.**—J. Cran \* deals with the forging of hooks and chains.

**Ordnance.**—A. T. Dawson † gives an excellent historical account of the manufacture of ordnance. Dealing first with the construction of the tube, he shows how the three principal problems—of insuring that large hollow forgings shall be even and regular in mechanical properties; of overcoming the mechanical difficulties of producing large masses of steel free from flaws, &c., and of producing great masses of steel of high tensile strength and elastic limit without brittleness—have been solved, and contrasts the wire-wound with the solid steel system of gun construction. The subject of explosives is dealt with at some length, and full particulars of the mountings for naval guns are given, together with illustrations of the ordnance produced by Armstrong, Krupp, Vickers, & Schneider.

P. Siwy ‡ has made some very interesting experiments on the wear of heavy ordnance, which have an important bearing on the results obtained by Krupp in testing guns of their own manufacture; it would appear that the superiority of special Krupp steel in wearing power is not conclusively proved.

E. F. Lake § describes and illustrates the manufacture of large guns at the works of the Bethlehem Steel Company, Bethlehem, Pennsylvania.

**Pickling Plates and Castings.**—G. Charpy || describes a new method for pickling iron sheets and wire, and for the recovery, from the liquors, of sulphate of iron. The methods at present in vogue are irregular in their results, fresh baths acting naturally with more energy than partially exhausted baths, and the metal to be treated having to be left for varying periods in contact, the length of time being determined by rough empirical methods, according to the strength and freshness of the bath liquor. To pickle in a more scientific manner it would be necessary to maintain the strength of the bath within narrower limits in order to determine more accurately the duration of immersion and the temperature required. Even liquor heavily charged with sulphate of iron will give excellent results, provided the amount of free acid present be sufficient. The new method is based, therefore, on the employment of a method for the precipitation of the sulphate, without any need for evaporation, simply by utilising the known variations in solubility of the salt at varying temperatures. To begin with, a 15 per cent. sulphuric acid solution, saturated at 15° with sulphate of iron, is employed. This solution is placed in the pickling vat and heated to 80°, and used for

\* *Machinery*, vol. xv. pp. 605–607.

† Lecture delivered before the Junior Institution of Engineers, June 30, 1909; *Engineering*, vol. lxxxviii. pp. 28–33, 61–67, 98–100.

‡ *Engineering*, vol. lxxxviii. pp. 123–124.

§ *American Machinist*, vol. xxxii. Part I. pp. 553–558.

|| *Revue de Métallurgie, Mémoires*, vol. vi. pp. 697–699.

pickling until the amount of free acid remaining has fallen to 10 per cent. The solution, enriched by approximately 170 grammes more sulphate per litre, yet still unsaturated, is now transferred to a vat, in which it is allowed to cool down to 15°, during which it deposits its surplus sulphate. A further 5 per cent. of acid is now added, which brings it back to the 15 per cent. strength it previously possessed, and is accompanied by a further deposition of surplus sulphate, and the solution now becomes identical with that first employed, and can at once be used again after the withdrawal of the surplus and deposited sulphate. The foregoing quantities are found to give regular and satisfactory results, and the method has been employed successfully at the Forges de Commentry for the pickling of sheets, and at the Vierzon Works for pickling the wire used in the manufacture of nails.

U. Lohse \* describes four different arrangements of pickling machinery, giving the general arrangement and also the details of the machinery for picking up, transporting, raising, lowering, and rinsing the plates. These are: (1) Simple pickling machine with straight path; (2) double pickling machine with straight path; (3) three-armed pickling machine with circular path; (4) four-armed pickling machine with circular path. Illustrations in the text show the various operations.

The process of pickling castings is described, and suggestions as to the solution to be used are also given.†

The new regulations of the Home Office relating to the tinning of metal goods have been issued. The coating of articles with a mixture of tin and lead, or with tin, has been certified as dangerous, and the conditions under which the operations may be carried on have been defined.‡

**Silvering of Steel, Nickel, and Nickel Alloys.**—The coating of steel or nickel direct with silver is possible only by using special silver electrolytes. One process, among those that have been tried, consists in placing the article in a bath under a high tension current, containing 1 gramme of pure silver and 50 grammes of 99 per cent. cyanide of potassium per litre of electrolyte. The operation can afterwards be continued in the ordinary silver bath. The process is not free from objections, however, owing to the difficulty of getting uniform results, and it is more satisfactory to coat with copper first.§

**Enamelling.**—E. A. Schott|| describes regenerative gas-furnaces for enamelling and other purposes. These furnaces require from

\* *Stahl und Eisen*, vol. xxix. pp. 893-899, 946-950.

† *Foundry Trade Journal*, vol. xi. p. 494.

‡ *Engineer*, vol. cviii. p. 164.

§ *Eisen Zeitung*, vol. xxx. p. 495.

|| *Giesserei Zeitung*, vol. vi. pp. 171-174, 195-197.

two-thirds to one-half the fuel consumed in an ordinary furnace with solid fuel. For small works each furnace should have a separate producer.

K. Rietkötter \* describes practice in the manufacture and enamelling of large iron vessels of capacities up to 200 hectolitres.

\* *Stahl und Eisen*, vol. xxix. pp. 1273-1276.

## PHYSICAL PROPERTIES.

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**Tests on Cast Iron and Steel.**—C. Jüngst\* communicates the results of experiments made on the strength of cast iron taken from one and the same charge, but cast under different conditions. The samples varied in thickness from about  $\frac{3}{4}$  of an inch to  $2\frac{1}{2}$  inches, and comprised pieces cut from plates and from the walls of box-shaped vessels, and also specially cast bars. Bending, tensile, compression, and impact tests were made. In general, the separately cast samples showed greater strength than those cut from larger castings, except in the case of the impact and bending tests. It appears that slow cooling diminishes the strength of cast iron, and that the temperature in general plays a more important part than has hitherto been assumed. The results of the tests are given in the forms of diagrams and tables.

A. F. Nagel† details the results of examination and study of a large number of test-bars for castings used in the Baltimore sewage pumps. Tables showing analyses and tests obtained on transverse and tensile bars are given, and the most important conclusion arrived at is that the test-bar is not to be regarded with too much confidence as indicative of the exact strength of the casting.

From his tests performed on cast iron, C. Frémont‡ concludes that the coefficient of elasticity varies within wide limits. He finds that the coefficient of elastic flexion is inversely proportionate to the resistance, which explains the failure of tension and impact tests to furnish information on the mechanical resistance of the metal. Under static flexion the elastic limit varies considerably, from 45 to 80 per cent. of the ultimate yield, and it must therefore be measured exactly. The shearing test furnishes data as to the ultimate yield under static flexion; and good cast iron should give a shearing strength of at least 18 kilogrammes per square millimetre.

F. J. Cook,§ in a lecture before the Birmingham branch of the British Foundrymen's Association, dealt with mechanical testing in the foundry. Some of the experiments which have been previously

\* *Stahl und Eisen*, vol. xxix. pp. 1177-1182.

† *Journal of the American Society of Mechanical Engineers*, vol. xxxi. pp. 1057-1063.

‡ *Bulletin de la Société d'Encouragement*, vol. cxi. pp. 943-968.

§ *Foundry Trade Journal*, vol. xi. pp. 395-398.

described by the author were illustrated, one of the tests in question being that of shrinkage. The machines used for testing hardness were dealt with. Another method of testing was that of drilling, and in fixing a standard for this test the author preferred taking the number of revolutions necessary to drill to a given depth, as this conveyed a better appreciation of the difference in hardness. The results of seventy consecutive tests with the same class of hard iron had shown that hardness had been an important factor in the transverse and tensile results obtained. The question of blast pressure received very little consideration from foundrymen, but for the production of high-class work careful attention should be paid to this point.

F. J. Cook \* and G. Hailstone give the results of tests carried out to determine the effect of structure upon the physical properties of cast iron.

J. Guillemin † describes the result of the micrographic examination of a series of foundry irons containing a relatively high proportion of combined carbon and intended for the casting of cylinders for marine engines.

A description has appeared ‡ of a ballistic test on a cast-steel locomotive cylinder carried out at the Indian Head proving ground, Sparrow's Point, Maryland, for the purpose of ascertaining the extent of internal strains. The casting, although thoroughly annealed, was made of the same steel mixture as several other cylinders cast at the same time. A test-bar from this heat showed a tensile strength of 76,500 lbs. per square inch, an elastic limit of 37,500 lbs. per square inch, an elongation of 26 per cent., and a reduction in area of 31·2 per cent. The analysis showed: carbon, 0·29 per cent.; manganese, 0·50 per cent.; sulphur, 0·034 per cent.; phosphorus, 0·034 per cent.; and silicon, 0·357 per cent. The thickness of the metal varied from 1 to 4 inches. The results of the test proved conclusively that whatever internal strains existed in the steel were removed by the annealing process, notwithstanding the disproportionate thickness of the metal in the cylinder. The test also served to disprove the contention that so difficult a casting as a locomotive cylinder could not be cast in steel.

J. E. Howard § gives some notes on tests of ingots and derivative shapes that are in progress at Watertown Arsenal. The object of the tests is to obtain information as to the causes which detract from the soundness of the structure of the ingots, and in order to attain this object the material, from the ingot to the finished rails, is examined on both longitudinal and transverse sections of the different shapes. The sections are polished and etched, and photographic records are obtained by means of which the successive changes in the appearance

\* Paper read before the British Foundrymen's Association; *Foundry Trade Journal*, vol. xi. pp. 553-559.

† *Revue de Métallurgie, Mémoires*, vol. vi. pp. 946-950.

‡ *Iron Trade Review*, vol. xliv. pp. 803-805.

§ Paper read before the American Society for Testing Materials, June 29, 1909; *Iron Age*, vol. lxxxiv. pp. 90-92.



of the steel from pass to pass are noted. Photomicrographs are given.

E. Heyn \* and O. Bauer have found that in testing steel containing 5.5 per cent. of nickel, the cracks which occur are due not to faulty structure, but to the fact that a certain limit of temperature, dependent upon the length of the reheating period and on the size of the forging, has been exceeded.

**Influence of Manganese on Cast Iron.**—H. E. Field † considers that manganese only indirectly affects the hardness of cast iron. The higher the percentage of manganese the greater is the proportion of carbon that is absorbed. Other conditions being equal, cast iron is softer the higher the total carbon, and the addition of manganese would therefore, in some cases, tend to produce a softer iron. This tendency of the manganese to soften the iron is, however, counteracted by its capacity to produce combined carbon, or carbide carbon, which having a hardening effect, has led to the supposition that the manganese itself confers hardness. On the other hand, by the removal of sulphur, which tends to make the iron hard, the manganese again has the effect of softening it. Tests in Germany have shown that by the judicious use of manganese ore and limestone cast iron can be desulphurised in the cupola, but this method is not to be recommended on account of the risk of unduly increasing the proportion of manganese in the iron.

**Silicon.**—C. I. Zimmerman ‡ discusses the physical properties of crystalline silicon. Concise data are given of atomic weight, specific gravity, molecular state of aggregation, tenacity, expansion with temperature, tensile strength, hardness, porosity, melting point, vapour tension, specific heat, latent heat of fusion, heat of combustion, thermal conductivity, optical properties, spectrum, magnetic properties, electrical properties, thermo-electric properties, and electrical resistance.

**Homogeneity of Steel.**—J. F. Springer § describes the Harmet process of ingot compression. The results of compression are dealt with, and photomicrographs comparing the structure in various parts of compressed and uncompressed ingots are given, together with tables showing the results of tensile tests on specimens cut from the cross-sections of slabs containing the vertical axes of Harmet and uncompressed ingots respectively.

M. H. Wickhorst || deals with the failure of a locomotive driving axle. The failure was due to a crack developing internally. Illus-

\* *Mitteilungen aus dem Königlichen Materialprüfungsamt*, vol. xxvii. pp. 1-7.

† *Eisen Zeitung*, vol. xxx. pp. 342-343.

‡ Paper read before the American Electrochemical Society, May 1909; *Electrochemical and Metallurgical Industry*, vol. vii. p. 280.

§ *Iron Age*, vol. lxxxiii. pp. 2002-2007.

|| Paper read before the American Society for Testing Materials, July 1, 1909; *Iron Age*, vol. lxxxiv. p. 123.

trations are given showing the fractured surface of the axle and an etching of a section near the point of fracture. Indications point to the fact that the billet was rolled from the ingot before the steel had solidified in the centre, leaving the process of crystallisation to go on after the work of rolling the billet had been finished.

H. M. Howe\* gives the results of an investigation of the conditions under which cavities are found in steel ingots in view of the contention that such cavities are hermetically sealed.

J. A. Murphy† recommends the use of steel scrap in cupola practice to close the grain of the metal, reduce the graphitic and total carbon according to the percentage of scrap used, and through quicker cooling, distribute the carbon more minutely and evenly through the section. Scrap additions prevent sponginess and segregation, lessen liability to cracking, add to the tensile and transverse strength, increase deflection and modulus of rupture, and give a high resistance to shock.

**Structure of Iron and Steel.**—A. Baykoff‡ discusses the structure of steels at high temperatures. Despite numerous investigations made on the subject the nature of austenite has not, up to the present time, been defined with sufficient accuracy, although the best definition appears to be that given by H. Le Chatelier, according to which austenite is a solution of carbon in  $\gamma$ -iron. The total amount of carbon cannot exceed 2 per cent., and the solution is stable from the solidification point of the molten metal to a transformation point which, in accordance with the amount of carbon present, varies from 700° to 1200°. It is impossible to retain this solid solution at ordinary temperatures except by vigorous quenching, and even then successful treatment is rare, and hardly ever complete. It has never been possible, up to now, to secure pure austenite at ordinary temperatures, it being always intermixed with an aggregate of martensite, troostite, and cementite. In the presence of sufficient nickel or manganese, however, this solution remains stable down to ordinary temperatures. These alloys are not magnetic, and have a high degree of magnetic resistance as  $\gamma$ -iron. More recently Maurer has obtained austenite by quenching at 1100° a ferro-carbon-manganese alloy containing 2 per cent. of carbon and 2 per cent. of manganese in iced water. This austenite is the purest hitherto obtained, but it contains 2 per cent. of manganese. Thus it becomes impossible to investigate the structure of austenite except at temperatures at which it reaches stability, that is to say, between 700° and 1200°, according to the amount of carbon present. With this object a series of experiments were devised, the results of which are given in detail, with analyses of the steels employed, an account of the treatment of the samples, and photomicrographs of the etched specimens. The samples were,

\* Paper read before the American Society for Testing Materials, July 1, 1909; *Iron Age*, vol. lxxxiv. p. 101.

† *Castings*; *Foundry Trade Journal*, vol. xi. p. 566.

‡ *Revue de Métallurgie, Mémoires*, vol. vi. pp. 829-834.

after preparation and polishing, introduced into a porcelain tube and placed in an electrical resistance furnace. Air was expelled by passing a current of pure dry hydrogen through the tube for some hours, the current being continued throughout the whole period of heating. When the necessary temperature has been attained hydrochloric acid is introduced, and the polished surfaces of the samples etched for a few seconds. The hydrogen current is continued, to expel all traces of hydrochloric acid, an operation which takes nearly two and a half hours; and the apparatus is then allowed to cool, when the samples are ready for examination. This method is advocated in preference to that proposed by Saniter, who has endeavoured to ascertain the structure of steels at high temperatures by etching the polished surface with fused calcium chloride. The plunging of the sample in the bath of fused salt cools it down and alters the structure, which affords an explanation of the reason why Saniter obtained a martensitic structure when treating an ordinary steel by his method.

L. Guillet \* classifies the special steels met with in commerce into the four following categories:—

- (1) Pearlitic steels, with or without cementite.
- (2) Steels enclosing, together with pearlite or sorbite, carbides which appear to have a more complex nature than cementite.
- (3) Martensite steels and those containing troostite.
- (4) Polyhedral steels, or steels containing  $\gamma$ -iron.

Of all the special steels in actual use the pearlitic steels are the most important. In their preparation it is sought to realise the following objects: a general intensification of the mechanical properties usually deemed desirable, and a simplification in the nature of the heat treatment necessary to bring out their best qualities. The first step accomplished in the latter direction has been the omission of a tempering operation. A composition has been sought, such that the degree of brittleness existing after quenching should not be sufficient to require a tempering operation to remove it. The best composition for various special steels is enumerated in a series of comparisons, in which the respective compositions and the leading mechanical properties are set out together with data relating to their temperature of annealing and that of quenching.

C. A. F. Benedicks † describes a form of bead pearlite. Micrographs are given showing results which were obtained from grey pig iron from Herräng heated to 670° C., having the following composition:—

	Per Cent.
Carbon . . . . .	3·9
Silicon . . . . .	0·75
Manganese . . . . .	0·37
Sulphur } . . . . .	low
Phosphorus }	

This bead pearlite is doubtless a slightly constant transition form

\* *Revue de Métallurgie, Mémoires*, vol. vi. pp. 810-813.

† *Iron and Steel Times*, vol. i. pp. 135-138.

between laminated and granular pearlite, but is somewhat difficult to observe.

**Metallography.**—W. Rosenhain \* describes the progress made during the last ten years in the application of photomicrography to materials used in engineering. He points out what may be learnt by the use of photomicrography after fractures, and discusses the desirability of including an examination of the microstructure in the regular tests carried out on engineering material, noting the increasing use of "equilibrium diagrams" in the treatment of binary alloys.

L. Révillon † discusses, from a general point of view, the application of metallography to industrial operations.

W. G. Haldane ‡ describes apparatus employed in metallography, and deals with the preparation of material for the examination and applications of metallography.

As the result of experiments A. Kingsbury § finds that, for the purpose of polishing metals for microscopic examination, ordinary paraffin wax makes a good polishing bed, and that excellent polishing powders of certain grades are commercially available. The polishing powders in the order used were: commercial flour of emery; washed naxos emery, 3/0 grade; washed naxos emery, 7/0 grade; and soft optical rouge, light grade. The method of preparing the waxed discs and the treatment of the samples are described.

**Magnetic Properties of Iron and Iron Alloys.**—P. Weiss,|| in discussing the phenomena of ferro-magnetism and its bearing on the study of metals and alloys, emphasises the extreme importance of the influence of the magnetic criterium. The results it has yielded are well known, and it has been of the greatest use in the elucidation of the complex problems presented by the nickel steels. In their important researches on binary systems, Tammann and his followers never fail to have recourse to it whenever one of the constituent metals is magnetic, and even in certain cases where, although the constituent metals are not magnetic, their alloys are. In this connection may be cited the highly interesting alloys recently discovered by Heussler, in which the mixture of substances magnetically inert occasions the appearance of ferro-magnetism as intense as that of the most completely magnetic metals. Observation of the magnetic properties nearly always completes, from some point of view or other equally important, the laws deduced from the study of the melting curves, or lends to them some measure of verification. Generally speaking, however, the researches are confined to the qualitative observation of magnetism and to the determination of the temperature

\* *Nature*, vol. lxxx. pp. 250-252.

† *Revue de Métallurgie, Mémoires*, vol. vi. pp. 819-822.

‡ *Western Chemist and Metallurgist*, vol. iv. p. 315.

§ *Journal of the American Society of Mechanical Engineers*, vol. xxxi. pp. 615-618.  
*Revue de Métallurgie, Mémoires*, vol. vi. pp. 680-696.

at which it disappears. It is clear that the most characteristic properties evade detection in such summary investigations. Still, if quantitative magnetic measurements are not more widely employed, two reasons may be adduced in explanation. For lack of a satisfactory theory of ferro-magnetism some difficulty is experienced in taking into account the physical signification of the quantities measured; and, therefore, in choosing, amidst the various factors known as susceptibility, permeability, magnetic intensity, induction, magnetic force, remanence, and coercitive field, that magnetic quantity really corresponding thereto. On the other hand, although they may suffice for industrial purposes and for electrical construction, the technology of magnetic measurements is not, at present, sufficiently accurate for the study of the physical chemistry of metals and alloys. This want it is sought to fulfil by investigating as a corollary to the theory of ferro-magnetism, the question of whether metals, from the point of view of the temperature of the disappearance of magnetism, should be considered as existing in two distinct phases—corresponding, it will be seen, somewhat with the Osmond allotropic theory—or otherwise.

The results of the kinetic theory of magnetism, elaborated in respect of paramagnetic bodies, by Langevin and extended by Weiss to ferro-magnetic bodies, afford for the first time a rational explanation of the complex facts of para- and of ferro-magnetism. Langevin's theory is for para-magnetism what Bernoulli's kinetic theory of perfect gases is for the compressibility of the latter. Van der Waals has extended the latter theory to fluids in general by enunciating a hypothesis as to the mutual action of molecules of gases hitherto regarded as independent in their action. This hypothesis is expressed in terms of the internal pressure which, added to the external pressure, explains the high density of liquids by calling to its aid the properties of gases. In a manner strictly analogous Weiss conceives a "molecular field," which, superadding itself to the exterior magnetic field, explains by the laws of para-magnetic magnetism the high magnetisation of ferro-magnetic bodies. This hypothesis enunciates that the action of the whole of the molecules on any one of them is equivalent to a uniform magnetic field ( $H_m = NI$ ) proportional to the magnetisation  $I$ , and subject to the same directive influences. This hypothesis is then elaborated, and a theory of spontaneous magnetisation is adduced, this spontaneous magnetisation being regarded as the degree of saturation at a given temperature. A further result of the theory is the conclusion that there is no essential difference between a magnetised body and a magnetic body, that is, a highly magnetisable body. They are both equally magnetised to saturation; but whereas in one body the magnetisation is co-ordinated, in the other it is confused.

The state of spontaneous ferro-magnetism corresponds to what Osmond terms  $\alpha$ -iron, and the limit of this state is the temperature at which spontaneous magnetism disappears. A series of experimental observations bearing on this statement are given, and the apparatus employed in the investigations illustrated and described.

The next stage of the research is concerned with the question as to whether the different magnetic states correspond with distinct phases, and for this purpose the nature of the thermal phenomena accompanying the transformation  $\alpha$  to  $\beta$  is discussed, and subsequently the theory is applied to an investigation of the nature of the iron-nickel, iron-carbon, copper-cobalt, and nickel-tin alloys.

B. O. Peirce\* has published a note on peculiar magnetic properties on the excitation of a remarkably pure specimen of soft Norwegian iron, which had been used to form the core of an electro-magnet made for special use in a laboratory. The performance of the magnet fell far below what it should have been, and as the iron was the very best brand of soft Norwegian iron known in the market, it was thought that valuable information might be obtained by testing it chemically and magnetically. The analysis showed that this commercial iron was of extraordinary purity. It contained less than 0.03 per cent. of carbon, less than 0.047 per cent. of phosphorus, 0.03 silicon, and 0.003 sulphur. There was therefore nothing in its composition to account for the comparative uselessness of the magnet. Its response to magnetic excitation was also highly satisfactory. Magnetic tests, however, showed that when excited at least 10 consequent poles were created between the ends of the core. When the current was reversed these poles changed sign, but in many places outside the exciting coil the direction of the field was always opposed to what it would have been if these consequent poles had not existed. The iron had been annealed as carefully as possible, but it is well known that this soft iron is very apt to acquire slight differences of temper due to unequal heating.

E. Gumlich† and E. Vollhardt have determined the influence of the direction of rolling on the magnetic properties of iron plates.

T. Swinden‡ describes the continuation of an investigation of the magnetic properties of a series of carbon-tungsten steels. A decisive maximum hysteresis is found in the hardened series at about 0.52 per cent. carbon. The tempering of hardened magnets is discussed, and it is shown that apparently a definite value of intensity exists for every magnet. The correlation between magnetic and other properties is also discussed, and the importance of correct quenching temperature is mentioned.

In connection with the magnetic properties of manganese steel it is pointed out§ that a bar of manganese steel balanced on a knife edge remains in balance when acted upon by the field of a very powerful electro magnet. An electro-magnet which would lift 2 tons of soft steel, when laid upon a block of manganese steel gives so small a pull that the hand recognises no increased weight in raising the magnet.

\* *American Journal of Science*, vol. xxviii. pp. 1-8.

† *Elektrotechnische Zeitschrift*, vol. xxix. pp. 903-907.

‡ *Journal of the Institution of Electrical Engineers*, vol. xlii. pp. 641-684.

§ Paper read before the Western Society of Engineers; *American Machinist*, vol. xxxii. Part I. p. 959.

A coil passing a current and acting as a solenoid on a bar of manganese steel develops no magnetic quality.

The results of recent investigations on silicon and its influence on the electric and magnetic properties of iron are briefly reviewed.\*

S. Wologdine† states that the temperatures at which various compounds of iron are demagnetised have been determined. The powdered substances were immersed in a suitable liquid, which was placed in a magnetic field. The temperatures at which the particles ceased to form chains between the poles were observed, and the following values are recorded: Magnetic iron oxide, 525°; iron sulphide (pyrrhotine), 300°; iron carbide, 180°; iron phosphide, 445°; franklinite, 61°; and iron-tungsten carbide ( $2\text{Fe}_3\text{C}$ ,  $3\text{W}_2\text{C}$ ), 80°.

Experiments to determine the effect of previous magnetic history on the magnetisation of iron are described by E. Wilson,‡ G. F. O'Dell, and H. W. K. Jennings.

E. E. F. Creighton§ deals with the electrical testing of iron during annealing. The problem of annealing iron for electrical purposes involves, first, a knowledge of the chemical composition and process of manufacture; second, the proper treatment for bringing the hysteresis loss down to a practical value; and, third, the treatment necessary to prevent ageing of the iron after it is put into service. Two pieces of iron which have identically the same composition as far as ordinary chemical analysis can determine, may give entirely different values of core loss with identically the same methods of annealing. For example, a piece of steel from a Bessemer converter will invariably have a higher hysteresis value than steel from an open-hearth furnace, in spite of all the ordinary methods of annealing. It is probable that the differences are due entirely to the absorption of gas in one form or another. A description is given of a furnace which was designed to permit of the measurements of the hysteresis and eddy currents for all values of temperatures up to and down from the temperature where the iron becomes non-magnetic. The usual method of treatment was to begin with core loss measurements at room temperature, and to take these measurements gradually up to the temperature of disappearance of magnetism. When the temperature approached red heat the gas treatment was begun. Various excess temperatures were employed and various rates of heating and cooling were tried. It was found that certain gases had marked effects on the iron if they came into contact with it during the time that the temperature was above that where the magnetism appears. Some of the results are shown by means of curves, and from these tests the conclusion is drawn that the iron used has absorbed nitrogen and is approximately in the same condition as Bessemer steel.

R. Beattie|| and P. M. Elton state that ballistic methods of

\* *Engineering*, vol. lxxvii. pp. 732-733. † *Comptes Rendus*, vol. cxlviii. pp. 776-777.

‡ *Proceedings of the Royal Society*, Series A, vol. lxxviii. p. 1-9; *Nature*, vol. lxxxi. p. 28.

§ *Transactions of the American Electrochemical Society* vol. xiii.; *Electrician*, vol. lxii. pp. 1006-1007.

|| *Electrician*, vol. lxiii. pp. 299-301, 341-343.

measuring hysteresis are very accurate, but have the disadvantage that they are generally troublesome. A method is described that is quick in operation, and has the advantage that it refers to short test-pieces. Instead of obtaining the B-H curve, the  $\delta$ B-H curve is found by a differential measurement, the method preferred being that of momentarily short-circuiting a resistance in the magnetising circuit so that H is brought up to its maximum value, and immediately returns to its previous value, a single specimen being used. The conditions for the interval of short-circuit are examined. The results are satisfactory, but the authors find that the loss in a ring is 1.65 times that found in strips, whether by the differential or step-by-step method. Finally some differential methods involving two specimens are described.

M. G. Lloyd \* and J. V. S. Fisher consider the most suitable conditions under which the hysteresis and eddy current losses in sheet steel may be tested by alternating currents. A table is given showing these losses at flux densities of 10,000 and 5000 and frequencies of 60 and 30, and the percentages of silicon for twenty different specimens of ordinary transformer steel and twelve specimens of silicon steel.

P. Krassa † describes experiments on the passivity of iron in caustic alkali.

**Stresses in Steel.**—C. A. Smith ‡ discusses the elastic “break-down” of metals. The results of researches conducted by means of his instrument, the sphingometer, showed that so far as the elastic properties of the material were concerned mild steel was very much more trustworthy than any non-ferrous metal. The sphingometer is capable of measuring extensions of a quarter of a millionth part of an inch.

L. Bairstow § states that the results of his investigations on stresses in steel are in harmony with the theory advanced by Bauschinger in 1886 in explanation of fatigue. It is shown that, between certain limits, and after a sufficient number of repetitions, iron or steel is capable of adjusting itself to cyclically applied variations of stress, the specimen becoming perfectly elastic throughout the whole cycle—when the adjustment is complete—without the occurrence of fatigue. A change of length, corresponding to that observed in an ordinary tensile test when the yield stress is exceeded, occurs in the specimen during the adjustment of the elastic limits to a given cycle of stress; but in the latter case the elongation is obtained even when the maximum stress in the cycle is less than the static yield stress, the increase in elastic limit being greatest in specimens showing the highest elongations. Below the static yield point iron and steel appear to be capable of maintaining their initial

\* *Bulletin of the Bureau of Standards*, Washington, vol. v. pp. 453–482.

† *Zeitschrift der Elektrochemie*, vol. xv. pp. 490–500.

‡ Paper read before the Institute of Metals, October 15, 1909.

§ *Proceedings of the Royal Society*, Series A, vol. lxxii. pp. 483–485.



condition for a considerable time against cyclical variations of stress which ultimately produce a considerable change of length.

**Damping down of Vibrations as a Test of the Properties of Iron.**—A. Guillet \* points out that when a metallic rod fixed at one of its extremities is elastically deformed by bending and then left to itself, it regains a position of equilibrium after having executed a series of more or less damped oscillations. The degree of damping necessarily depends on the internal structure, and on the viscosity of this structure, so that an investigation of the behaviour should furnish useful information. In regard to iron and steel, for example, it is possible to distinguish by this means between different specimens of iron. Thus the degree of damping in vibrations of a U-shaped bar of soft iron is on the average three times as great as that which under similar conditions those of a U-shaped bar of soft steel would undergo. In order efficiently to measure the degree of damping, it is necessary to set the sample in vibration under the form of a cylindrical rod, or, better still, one of prismatic shape, to amplify the degree of oscillation sought, and, if desirable, to maintain it constant for some hours, and on liberating the rod, to be able to read for any given moment the corresponding value of the amplitude. The results of experiments carried out under these conditions are given, and it is suggested that it should be possible to deduce by means of this method interesting details relative to the properties of the metals under investigation.

H. Le Chatelier,† commenting on the suggestion of A. Guillet, considers the proposal one of extreme interest, as opening an unsuspected field for scientific metallurgical investigation. The elementary properties of metals, to which attention is thus drawn, are distinct from any which can be ascertained by the ordinary methods of observation hitherto practised.

**Impact Tests and Testing Machines.**—L. Guillet‡ and L. Révillon have carried out a series of experiments relating to (1) the influence of the rate of impact on the curve of resilience in terms of the temperature, and (2) the influence of different elements on this curve. To elucidate the first-named consideration, a steel containing 0.35 per cent. of carbon, 0.20 per cent. of silicon, 0.51 per cent. of manganese, 0.048 per cent. of sulphur, and 0.068 per cent. of phosphorus was used. The steel had been annealed in a closed vessel for half-an-hour at a temperature of 850°. Three series of experiments were made, with a Guillery falling weight machine. A table comparing the results obtained at the different temperatures is given. A series of separate tables likewise embody the results of further series of tests on special steels of specific microstructures similarly tested at varying temperatures.

\* *Revue de Métallurgie, Mémoires*, vol. vi. pp. 885-887.

† *Ibid.*, pp. 887-889;

‡ *Ibid.*, pp. 918-924.

L. Grenet\* has undertaken some experiments with the object of ascertaining the amount of work which test-pieces are able to withstand when submitted to shock. Diagrams and illustrations, showing the form of the test-pieces, and mathematical formulas giving the results, accompany the investigation. The conclusions arrived at are :—

(1) The total work done in breaking a test-piece is considerably greater than the amount of work which indefinitely repeated would lead to breaking. Nor is there any reason at first sight to suspect any relation between the respective values. When a test-piece undergoes shock stresses which exceed those that it could withstand indefinitely without breaking, only a fraction of the work done by the shock stresses, the maximum elastic limit of the metal being exceeded, is necessary to occasion breakage.

(2) The shock stress which the test-pieces usually experimented with are capable of indefinitely withstanding is very low. It is not surprising, therefore, that in experiments hitherto carried out, the lower limit of shock resistance, which indefinitely repeated would lead to breakage, has not been ascertained.

(3) The coefficient of resistance to tensile stress, or that of elastic limit, which in static stresses is a constant, becomes proportional to its square under shock stresses.

(4) There is no reason to suppose that the coefficients deduced as the result of shock tests should differ from those given by tensile tests.

(5) It is even more important that test-pieces required to withstand shock tests should possess shapes of regular form than test-pieces submitted to static stresses.

A. Le Chatelier† reviews the discussions arising out of Guillet and Revillon's experiments on the influence of time and temperature on shock tests, and recalls some of his earlier investigations on this subject, in the light newly thrown on them by more recent researches. Those results showed that above a temperature of 80° to 100° iron and steel, under the influence of permanent deformative stresses, undergo a transformation which has the effect, under tensile stresses, (1) of raising the tensile strength, (2) reducing the elongation, and (3) reducing the contraction of area in the same proportion. This transformation is characterised by a very curious and up to now inexplicable phenomenon. The elongation proceeds spasmodically, which can be very clearly shown in operating on a wire. Instead of having, as usual at ordinary temperatures, a continuous elongation, there are a series of sudden increases in length, sometimes attaining as much as 2 to 3 per cent, but separated by intervals during which the load may be increased from 5 to 8 kilogrammes. From 200° to 250° this effect is destroyed by an annealing effect and the elongation becomes normal, the load diminishing and the elongation and reduction of area increasing. It cannot be too strongly

\* *Revue de Métallurgie, Mémoires*, vol. vi. pp. 835-841.

† *Ibid.*, pp. 914-919.

emphasised, that the mechanical properties observed at these temperatures are not due to the temperatures alone, but are caused by a transformation which occurs when permanent deformation intervenes. That this view is correct is shown by the following facts:—

(1) A steel which has at 150° undergone an elongation of 2 to 3 per cent. maintains, after cooling, a permanent deformation; its breaking strain rises by several kilogrammes; its elongation and reduction of area are reduced to less than a half; but this alteration disappears if the metal has been reheated for a sufficiently long period between 250° and 300°.

(2) At temperatures above 100° the results given by the tensile test vary enormously according to the duration of the stress, or, more accurately, with the rate of stress. Thus a dead soft steel possessing, at 15°, a tensile strength of 36 kilogrammes per square centimetre, gave, at 170°, only 27 kilogrammes after 2 seconds, but 45 kilogrammes after 20 minutes' testing. It would appear from these considerations that the mechanical properties of a steel below 100° are functions not of the temperature alone, but also of the time, and that the latter influences the results at least as strongly as the former. To draw trustworthy comparisons from tests of this nature it appears necessary, therefore, to make series of tests at different temperatures, and at different rates of application of the stresses.

An illustrated description is given \* of an alternating impact testing machine designed by F. K. Landgraf and W. L. Turner, with a view to providing means whereby impact tests (in which the rate of the blow imparted to the metal has not only to be kept constant, and in which the degree of deflection must be the same at every blow) may be performed under uniform conditions, and so render possible accurate comparison of results obtained by individual investigators. The results of tests, and illustrations of the final line of fracture in test-pieces, are also given.

**Tensile Testing Machines.**—A description is given † of the 300-ton testing machine that has been installed in the Engineering Department of the Birmingham University. The machine will test specimens in tension up to a maximum stretched length of 33 feet 6 inches. Columns or stanchions, up to a maximum length of 30 feet, can be tested in compression, while for transverse tests, beams, built-up girders, or roof-trusses complete, can be tested up to the maximum load, applied centrally between abutments set to any span up to 20 feet apart. Small specimens can be tested with equal facility.

**Hardness Tests and Hardness Testing Machines.**—F. Robin ‡ has carried out an interesting series of tests on the variations in the hardness of steel with the temperature. Beginning at air tempera-

\* *American Machinist*, vol. xxxii. Part I. pp. 641-642.

† *Iron Trade Review*, vol. xlv. pp. 1122-1123.

‡ *Bulletin de la Société des Ingénieurs Civils de France*, vol. lxii. pp. 433-459.

ture, the hardness of wrought iron and of the various descriptions of steel undergoes certain alterations on exposure to heat, which are dependent on the composition of the metal in question. The strength gradually diminishes, and finally disappears altogether on reaching the point of liquefaction. These variations in hardness, which seem to be very irregular, are from the industrial point of view of great interest, in so far as they concern a host of practical applications of metals. In the case of carbon steels the hardness is the same throughout, but special elements added in small quantities to steels greatly increase their hardness, and often diminish in a very high degree the extent of the variations in hardness due to an increase of temperature. Tungsten, and especially chromium, have a marked effect in this direction. In these compound steels there is no loss of hardness until the temperature rises to 600° C. A series of tests parallel to those conducted with the Brinell apparatus have also been carried out for hardness by tensile stress. The results obtained by these two methods appear to coincide.\*

T. Y. Olsen † describes a new hardness testing machine specially designed for testing locomotive tires. The machine consists of two levers mounted on a frame and having a combined scale of 100. The load is applied by weights at the end of one lever, which causes the penetration of a steel ball at the end of the other, the specimen being placed between the steel ball and the frame of the machine. The penetration is measured automatically to a ten-thousand part of an inch. The method of applying the load through a balanced lever is most accurate, as it is not subjected to variations, and can be verified at any time. The proper load, which is 5000 pounds for steel, must be learned by experience.

The Martens ‡ sclerometer is designed to obviate the calculations necessary in following Brinell's method, by measuring directly the depth of the indentation caused by the steel ball. It consists of two parts—an hydraulic press to force the steel ball against the specimen to be tried, and a measuring apparatus for gauging the depth of the indentation obtained. The small steel ball is fixed by wax into a block slightly hollowed to receive it, and the water-pressure on the block is regulated by a tap, and measured by a delicate apparatus in the outflow. The measuring apparatus consists of three points passing through a block, and acting on the face of a piston which communicates with the base of a tube filled with mercury, which in its turn communicates with a capillary tube with scale attached. To use the apparatus, the specimen to be tried is introduced and placed in contact with the steel ball. Water is then admitted till an indentation of the desired depth is produced, and the hardness of the material is measured by the pressure required, the deformation of the steel ball being so slight as to be negligible.

\* *Revue de Métallurgie, Mémoires*, vol. v. pp. 893-908.

† Paper read before the American Society for Testing Materials; *Iron Trade Review*, vol. xlv. pp. 257-258.

‡ *Genie Civil*, vol. liv. p. 342.

During the Congress of the International Association for Testing Materials, held at Copenhagen in September 1909, there were exhibited two hardness testing machines. One, constructed by L. Schopper of Leipzig to the design of A. Martens, applies ball pressure by determining the force essential for producing an impression of a certain depth, or by determining the depth corresponding to a certain force. In the second machine, which was of the Brinell type, the cone-pressure test system was illustrated. This test is the transition stage from ball pressure to scratch methods, and the apparatus, as usually made, may be combined with the press of any Brinell ball-test instrument. The object of the cone test is to make the hardness number independent of the load and of the dimensions of the impression. In the machine shown at Copenhagen by the Aktiebolag Alpha, Stockholm, the diameter and not the depth of the impression was measured. The twin plunger giving a mean result is a very neat device.\*

**Tool Steel.**—Particulars are given of tests on steel-turning tools and drills, carried out at the Sheffield test-house, and tables of the results obtained are published.†

A. F. Shore,‡ in discussing high- and low-carbon steel for tools, states that while low-carbon steels have limited resistance, particularly to wear, it is often possible to obtain great strength and performances which are excellent. These steels are, as a rule, more difficult to handle than the higher carbon steels, for the reason that their strength is dependent for the most part on the fibre compression, which is either destroyed during annealing or by the most trifling overheating.

Copies have been published § of reports submitted by the Board on Tool Steel, to the Naval Construction Department, Washington, containing the specifications for high-speed tool steel which have been adopted in accordance with the recommendations of the Board contained in the first report. The report deals with the qualities desirable in tool steel, and the chemical composition necessary to obtain those qualities, the shapes and sizes desirable, and the tests the steels should fulfil.

J. M. Darke || gives a specification for carbon tool steel. The steel is divided into five classes and three grades, and a table is given showing the class and grade of steel for various purposes. The methods employed in the chemical analysis of the steel are also briefly described.

H. Williams ¶ deals with the United States navy specifications for tool steel, and gives the chemical composition and physical characteristics adopted for such steel, especially high-speed steel.

\* *Times Engineering Supplement*, September 15, 1909, p. 16.

† *Engineer*, vol. cvii. p. 347.

‡ *American Machinist*, vol. xxxii. Part I. pp. 222, 987.

§ *Iron Age*, vol. lxxxiv. pp. 480-483.

|| *Ibid.*, pp. 483-484.

¶ *American Machinist*, vol. xxxii. Part II. pp. 187-189.

**Tests on Files.**—E. G. Herbert\* describes some experiments on the testing of files, and suggests having files specially cut for various metals, as those which are efficient for one metal may be quite unsuited to another. He also describes a new machine for the testing of files. The efficiency of different files of the same quality varies very greatly, and from results obtained with the machine it has been demonstrated that the two sides of a file are seldom equal in durability.

**Steel Rails.**—H. Fay† and R. W. G. Wint discuss certain types of rail fracture, with special reference to slag enclosures. An examination of split heads discloses: (1) excessive slag; (2) segregation of slag concentric with the section; (3) remnants of slag in the large split portion of the head; (4) slag in those areas where the flow of metal has occurred, or where microscopic cracks have developed. Cracks invariably begin in one slag area and lead to another, and may occur either on the surface or well within the metal. The authors suggest as remedies, that lower sulphur should be specified, that more time between the addition of ferro-manganese and the pouring of the metal into the ingot mould should be allowed, and that bottom-pouring should be resorted to. Electric refining might remove many of the difficulties.

P. H. Dudley‡ has examined the occurrence of split rail heads, and discusses certain peculiarities in the neighbourhood of the split. Dark carbon streaks have been noted which are distinctly harder than the surrounding metal, and the carbon in the streaks is found to be considerably higher than the average percentage of carbon in the rail. The streaks do not appear to be an ordinary segregation effect. Examination of the bottom plates upon which the ingot mould is set shows that after a number of heats the latter lose from 30 to 40 lbs. weight of metal, and this average loss seems to occur when the steel is high in temperature.

According to R. Job,§ the increase in the production of open-hearth rails is due to the fact that the lower phosphorus percentage permits a higher carbon content than is admissible with the high phosphorus Bessemer rails. However, the fact that the rails are of open-hearth steel is no guarantee that they are certain to give good service. The author quotes one which had broken in service into about forty pieces. Results of analysis showed that radical segregation in the ingot existed, which accounted for a decided difference in the physical properties of the steel in closely adjacent parts.

The wear of standard steel rails on the London underground railways has been found to be excessive under electric traction. Rails which were expected to last five years have had to be removed within periods of five months to two years, and exceptionally heavy

\* *Engineer*, vol. cviii. p. 349.

† Paper read before the American Society for Testing Materials; *Engineering Review*, vol. xxi. pp. 262-263.

‡ *Ibid.*, p. 262.

§ *Ibid.*, pp. 261-262.

1909.—ii.

side cutting at curves has taken place. As a remedy for the trouble high-silicon rails have been tried, the life of which is found to average much longer than the ordinary rails. The percentage of silicon in these is 0.35 to 0.45, and they contain 0.45 to 0.55 per cent. of carbon.\*

W. S. Potter† deals with the composition of manganese steel, its physical properties, tensile tests, heat treatment, and rolling, and gives specifications for manganese steel rails.

C. V. Slocum‡ discusses the use of titanium in steel for the manufacture of rails, car wheels, &c. The element titanium is introduced into the steel in the form of the alloy ferro-titanium, which contains from 10 to 15 per cent. titanium, 5 to 7 per cent. carbon, and less than 0.5 per cent. other impurities. The balance, some 80 per cent., is iron. By the use of titanium Bessemer steel is improved, so that it becomes better than ordinary open-hearth steel; it brings open-hearth steel nearer to crucible steel quality, and it is possible, by its aid, to improve even electrically refined steel of crucible steel quality. Trials made in connection with Bessemer steel show that the addition of the alloy causes an unprecedented increase in the quantity of slag removed from the steel. The treated metal invariably lay "dead" in the ingot moulds, was absolutely free from blowholes, and the titanium treated ingots were noticeably hotter than the untreated ones. In open-hearth steel the increase in the quantity of slag removed or "lifted" by the alloy is almost as remarkable as in the Bessemer product, and the general characteristics of the metal are freedom from blowholes, increase of elastic limit, and greater reduction of area. To sum up, the effect of titanium alloy in steel is to remove the oxides and nitrides, to increase the fluidity and temperature of the metal, and to increase the quantity of slag, which it not only removes, but with which the titanium itself passes off. The resulting product is stronger, more durable, and more easily machined, and the casting heats less under the tool, and gives greater resistance to shock, strain, or wear.

Photographs and provisional results relating to the comparative wear of titanium steel rails and rails of ordinary standard Bessemer quality have appeared.§ The tests have been carried out on a curve on the Baltimore and Ohio Railroad, and have so far, after nine months, given results greatly in favour of the titanium rails, which have worn well through the whole period, whereas the Bessemer rails became so worn that they have had to be renewed.

A new rail specification, designed particularly to provide against the severe weather conditions in Canada, has been prepared by the Canadian Pacific Railway. The Bessemer rails have only 0.085 per cent. of phosphorus, and the average carbon is 0.58, while for open-

\* *Light Railway and Tramway Journal*, June 11, 1909.

† *Journal of the Western Society of Engineers*, April 1909.

‡ *Electrochemical and Metallurgical Industry*, vol. vii. pp. 128-130.

§ *Iron Age*, vol. lxxxiv. pp. 394-396.

hearth steel the limit for phosphorus is 0.06 per cent., and the lower limit for carbon 0.60 per cent.\*

**Corrugation of Steel Rails.**—A. Busse † discusses the possible causes to which the corrugation of tramway rails may be ascribed. It appears that every tramway system of importance has experienced corrugation, and the general opinion is that its appearance is closely connected with the introduction of electric traction. The reputed causes are many, but in what proportion they contribute to produce corrugation is at present unknown.

**Steel for Structural Purposes.**—E. Marburg ‡ has carried out an investigation for the purpose of determining the comparative values of the Grey beam and the standard beam. The tests failed to establish the superiority of the Grey beam, it being demonstrated that while the elastic limit of the standard beam is very constant at about 20,000 lbs. per square inch for all sections, that of the Grey beam falls off rapidly, being only 10,800 lbs. for girders 30 inches deep.

A. Jacobson § contributes an illustrated article, giving a brief summary of the experience with nickel steel in bridge construction, and pointing out the possibilities of thereby reducing the dead weight of such constructions. The effect of varying the percentages of nickel and of carbon is discussed, and a detailed account given of the experiments of J. A. L. Waddell. The result appears to be that nickel steel may be most advantageously used for parts of considerable size subjected to high stress; less advantageously for those subjected to normal stress, and with little advantage in supplementary parts. The objection to using nickel steel and ordinary steel together is, first, that not being very different in appearance, greater care in the work is necessary to prevent the two steels being confused; secondly, that being probably differently affected by temperature, unfavourable secondary effects may result. The higher price of nickel steel prohibits its use except in cases where its superiority is very marked.

W. R. Webster, || in carrying out tests for the American Bridge Company, preparatory to the making of the nickel steel eye-bars for the Blackwells Island Bridge, specifies the ultimate strength of unannealed test-bars at 95,000 to 110,000 lbs. per square inch, and of the full-sized bars at 80,000 lbs. per square inch, with 48,000 lbs. per square inch as the elastic limit.

In his presidential address to the American Society of Testing Materials C. B. Dudley ¶ discusses the causes of failures in engineering structures.

\* *Railroad Age Gazette*; *Iron Age*, vol. lxxxiii. p. 1301.

† *Official Circular of the Tramways and Light Railways Association*, July 1909.

‡ *Engineer*, vol. cviii. pp. 220-221.

§ *Génie Civil*, vol. liv. pp. 351-355.

|| *Proceedings of the American Society of Civil Engineers*, vol. xxxv. pp. 276-288.

¶ *Iron Age*, vol. lxxxiv. pp. 21-23.



**Strength of Riveted Joints.**—The commission of the Verein deutscher Brücken- und Eisenbaufabriken\* has issued a report on tests carried out on riveted structures. Butt-joints made by a lever-riveting machine driven by compressed air were stronger than when hand-hammered or pneumatic-hammered. The use of countersunk rivets had no special influence upon the resistance to slip or the ultimate strength of the joint. Whether snap-headed or countersunk rivets were used the heads always sheared off from the shanks, and the form of rivet recommended for adoption is the ordinary snap-headed one with slightly rounded corner under the head.

C. Frémont† considers that the main point to bear in mind in riveted structures is to secure the maximum surface-friction, for which purpose a knowledge of the determining factors is essential. Within limits the riveting temperature does not affect the result, although a low temperature (900° C., for example) is advisable, in order that the rivets may fit the holes, and that the quality of the metal may not suffer injury. As overheating is also injurious, the above temperature should not be exceeded in heating the rivets, and a reverberatory furnace is the best to employ. The elastic limit of the metal after riveting is a most important feature. The special nickel, chromium, and other steels with low transformation points are less suitable for rivets than ordinary carbon steels. The contact surfaces of the plates should be carefully straightened. The tensional stress in the rivets is not materially affected by their length, and indeed long rivets may give the maximum resistance. Prolonged application of pressure during riveting increases the strength by 10 to 60, and even 100 per cent. The best form of rivet head is hemispherical (diameter two-thirds that of the shank), with a small peripheral flange.

**Reinforced Concrete.**—E. Brown‡ gives particulars of tests on reinforced concrete beams made in the testing laboratories at the McGill University. Kahn, Johnson, and Ransome bars were used in the tests. The steel bars were arranged in all cases so that the centre line of the reinforcement was as nearly as possible  $\frac{1}{4}$  inch above the bottom of the beams.

F. von Emperger§ discusses the stresses in ferro-concrete due to the seasonal variation in temperature.

G. Lanza|| and L. S. Smith deal with stresses in reinforced concrete beams, the object being to make a comparison of (a) the position of the neutral axis, (b) the stress in the steel, (c) the stresses in the concrete, and (d) the deflection, as determined by experiment, with the same quantities as computed by three well-known theories of the

\* *Zeitschrift des Vereines deutscher Ingenieure*, vol. liii. pp. 1019-1025.

† *Bulletin de la Société d'Encouragement*, vol. cxi. pp. 653-712.

‡ *Transactions of the Canadian Society of Civil Engineers*, vol. xxii. pp. 245-363.

§ *Zeitschrift des oesterreichischen Ingenieur- und Architekten Vereines*, vol. lxi. pp. 349-353, 369-372.

|| *Journal of the American Society of Mechanical Engineers*, vol. xxxi. pp. 1035-1046.

distribution of the stresses. Experiments were made with eleven beams, and tabulated results of the tests obtained are given.

A formula for calculating the coefficient of elasticity of beams of reinforced concrete has been published by Pigeaud,\* based on the principle previously stated in 1900 by Considère. The coefficient of elasticity of reinforced concrete is only constant within the limits of the same concrete, not reinforced; beyond that it becomes plastic, and stretches with the steel contained in it, but without changing its tensile strength.

E. McCullough† gives formulas for the calculation of the comparative strength of timber and reinforced concrete.

Particulars are given of three recent cases in which reinforced concrete structures have collapsed, causing serious injury to individuals.‡

A. C. Auden§ discusses the standardisation of reinforced concrete and the methods of using it in the construction of buildings, boats and barges, drain-pipes, and dock and reservoir walls.

H. P. Kieffer|| has published an illustrated description of Gabellini's reinforced concrete boats and barges now coming into extensive use in Italy.

A. W. von Monteforte¶ discusses the use of reinforced concrete for ornamental structural work and mouldings in buildings.

Stephan\*\* considers the influence of surface water and spring water upon concrete structures, with special reference to the effect of carbonic acid and ferrous solutions.

**Specifications.**—The Engineering Standards Committee have now issued the British standard specification for cast-iron pipes for hydraulic power. Cast-iron pipes for hydraulic power as generally used fall naturally into two divisions, the greater number being for pressures from 700 lbs. to 900 lbs. per square inch, while in recent years higher pressures, from 900 lbs. to 1200 lbs. per square inch, have been extensively used. Two standard series have been drawn up to suit the respective pressures.

The new specifications for shapes, plates, and rails, prepared by a committee of the American Society for Testing Materials, have been published.††

The question of uniform boiler specifications has been made the subject of a report by the Committee on Uniform Specifications appointed by the American Boiler Manufacturers' Association. The text of the report is published ‡‡ in the account which has appeared

\* *Annales des Ponts et Chaussées*, 1908; *Génie Civil*, vol. liv. p. 360.

† *Mining World*, vol. xxx. pp. 423-424.

‡ *Echo des Mines*, vol. xxxvi. pp. 702-703.

§ Paper read before the Institution of Mechanical Engineers, July 1909.

|| *International Marine Engineering*, vol. xiv. pp. 287-290.

¶ *Zeitschrift des österreichischen Ingenieur- und Architekten Vereines*, vol. lxi. pp. 281-287.

\*\* *Armierter Beton*, 1909, pp. 95-98.

†† *Iron Age*, vol. lxxxiv. pp. 26-29.

‡‡ *Ibid.*, pp. 546-552.

of the twenty-first annual meeting of that Association, held in August 1909 at Detroit, Michigan.

The specifications for 33-inch cast-iron car wheels, adopted at the Convention of the Master Car Builders' Association held in Atlantic City, New Jersey, from 21st to 23rd of July 1909, have been published.\* Excessive weight will no longer be a cause for rejection, but no payment will be made to the maker on account of the excess. The minimum depth of chill in the tread has been slightly increased, but the drop and thermal tests have been changed but little.

**Laboratories.**—A full description of the buildings and equipment of the laboratories of the University of Birmingham has been published.†

A description is given ‡ of the new engineering laboratories of the Manchester University.

An illustrated description has appeared § on the new engineering laboratories and workshops of the Heriot-Watt College, Edinburgh.

An illustrated article has appeared || on the testing laboratory attached to the Technical High School at Darmstadt, which includes a laboratory for the testing of materials, workshops for the preparation of samples both of metal and of other materials, a chemical laboratory, and a department for gas-engine trials.

\* *Iron Age*, vol. lxxxiv. p. 414.

† *University of Birmingham Engineering and Mining Journal*, July 1909, pp. 1-40.

‡ *Times Engineering Supplement*, July 28, 1909, p. 17.

§ *Engineering*, vol. lxxxviii. pp. 243-244.

|| *Génie Civil*, vol. liv. pp. 259-260.

## CHEMICAL PROPERTIES.

**The Theory of the Iron-carbon System.**—The equilibrium diagram of the iron-carbon alloys constructed by G. B. Upton \* is stated to give an entirely satisfactory explanation of the constitution of cast irons.† The effect of other elements on the percentage of carbon in cast irons of the eutectic composition or "saturated" cast irons is summarised. The author considers that a grey cast iron consists of graphite in a metallic matrix, which is a conglomerate of  $\gamma$ -solution crystals with varying contents of silicon and carbon in solution, phosphides and sulphides of iron and manganese being mixed with the metallic matrix. White cast iron is stated to be a super-saturated solution of carbon, with some silicon, in  $\gamma$ -iron, the crystals varying in composition. Thus the cementite crystals are those of the  $\gamma$  solid solution which first freezes out of the melt, and pearlite is the mass of the melt caught and held as a supersaturated solid solution.

F. Wüst ‡ deals at length with the influence of manganese on the iron-carbon system, and forms the following conclusions: The solidification point of iron is slightly lowered by the addition of manganese up to 13 per cent. A further increase of the percentage of manganese raises the melting point, which, with 80 per cent. of manganese, is about 1250° C.

The temperature of the formation of pearlite is, even with small quantities of manganese, considerably lowered, and the pearlite disappears completely with iron containing not more than 5 per cent. of manganese. The hysteresis is increased by an addition of manganese.

The solubility of carbon in iron is increased by an addition of manganese. With rapid cooling 50 per cent. of manganese suffices to render the solution of carbon possible up to complete saturation as carbide.

The eutectic point of pure iron-carbon alloys corresponds with 4.2 per cent. of carbon, but is slightly displaced by the addition of manganese, and for alloys with about 15 per cent. of manganese corresponds to 4.05 per cent. of carbon. The structure of iron

\* *Journal of Physical Chemistry*, vol. xii. pp. 507-549.

† *Ibid.*, vol. xiii. pp. 388-416.

‡ *Metallurgie*, vol. vi. pp. 3-14.

containing manganese changes in such a manner that the formation of pearlite is hindered by increasing percentages of manganese, and the formation of troostite and solid solution is favoured. Those alloys, which display no transformation point corresponding with pearlite formation, contain, instead of pearlite, a solid solution of carbide in  $\gamma$ -iron. The paper is illustrated with diagrams and photomicrographs.

Grenet\* combats the view that the transformation of pure iron is a phenomenon to be considered apart from the mutual solution of iron and carbon. He extends the idea of solid solution to pure bodies, and considers the transformation of pure iron as a limiting case. The passing of pure iron into solid solution may be regarded as the limit of its liquid solution in other constituents, when the proportion of these approaches zero. Steels are looked upon as containing only the three constituents—ferrite, cementite, and solid solution—and the phenomena relating to them, as falling in with the general case of alloys, of which the constituents can form solid solutions which may be decomposed at certain temperatures.

As a result of investigations made with regard to the formation of carbides, J. N. Pring† states that direct union of iron with carbon occurs at about  $700^{\circ}$  under a pressure of about 0.05 millimetre.

J. E. Stead‡ deals with alloys of iron, carbon, and phosphorus.

**Varieties of Carbon.**—H. Le Chatelier§ and S. Wologdine supplement the investigations made in 1908|| by a further series carried out in order to ascertain, by actual experiment, whether the view so widely spread amongst chemists as to the existence of numerous, and indeed almost an infinite number of polymeric varieties of carbon, was correct. The various allotropic modifications of a body are characterised by differences in their physical properties, and authors have ascribed to ordinary carbon widely variable densities and heats of combustion. Graphite differs considerably from ordinary carbon, with which it is often mixed. Not only does ordinary carbon become transformed into graphite at electric arc temperatures, but the carbon produced at much lower temperatures is often a mixture of graphite and ordinary carbon. The carbon which separates from a pig iron annealed at  $700^{\circ}$  is wholly in a state of graphite, while that produced on the decomposition of carbon bisulphide, at a much lower temperature, consists mainly of graphite. Before the properties of ordinary carbon can be investigated, it is therefore necessary to insure the complete absence of graphite, an operation of greater delicacy than might be imagined. The reaction characteristic of graphitic oxide,

\* *Bulletin de la Société Chimique*, vol. v. pp. 758-764.

† *Electrochemical and Metallurgical Industry*, vol. vii. p. 121.

‡ Paper read before the Seventh International Congress of Applied Chemistry, London.

§ *Comptes Rendus*, vol. cxlviii. pp. 1715-1718.

|| *Ibid.*, vol. cxlvi. p. 49.

which is sharply defined in the case of natural graphite, which is always lamellar, becomes exceedingly difficult to employ in the case of the fine pulverulent carbon obtained in certain laboratory reactions. The graphitic oxide, a totally insoluble body, preserves the form of the particular carbon oxidised. In the case of natural graphite it reveals itself in yellow scales of relatively large size, which decompose rapidly in water and in saline solutions. It is easily recognisable at sight. But in the case of finely divided carbon it takes the form of an impalpable yellowish powder, which remains for a long time in suspension in liquids, its washing by decantation requiring much precaution and time. Deflagration on heating, with the accompanying formation of a voluminous black mass known as pyrographic oxide, serves, however, to characterise the graphitic oxide thus obtained.

**Separation of Graphite in White Iron.** — G. Charpy\* has investigated the question as to whether the well-known behaviour of graphite in separating from white pig iron when the latter is cooled down rapidly from a temperature of  $600^{\circ}$  to  $700^{\circ}$  persists when the iron is subjected to high pressures. The apparatus employed in the research is described and illustrated. The result of the experiments was that the decomposition of iron carbide at temperatures ranging between  $700^{\circ}$  and  $1100^{\circ}$  is always attended by the deposition of graphite, even when the pressure amounts to as much as 15,000 atmospheres.

**Silicon-iron Alloys.** — W. Gontermann† deals with the iron-carbon and iron-silicon systems. The author made an experiment on pure iron with 0.7 per cent. of carbon, 0.09 per cent. of silicon, 0.08 per cent. of manganese, 0.01 per cent. of phosphorus, 0.015 per cent. of sulphur, and 0.023 per cent. of copper, by which, in addition to the critical points at  $852^{\circ}$  and  $770^{\circ}$  C. he could determine a further point at  $1411^{\circ}$  C. This new point is considered as the transformation of  $\delta$ -iron into  $\gamma$ -iron. The existence of  $\delta$ -iron must be confirmed by further researches. A peculiar condition of the process of segregation of eutectic iron was observed. He determined the simultaneous occurrence of primary cementite together with primary mixing crystals, and explains this as follows: If a eutectic iron is cooled without solidification to slightly below the eutectic temperature, the mass is under-cooled with reference to both kinds of crystals, mixing crystals and cementite. If cooling ceases and solidification commences both kinds of crystals must in the first place separate simultaneously. The author simplifies the diagram of the iron-silicon system by giving the compound  $\text{Fe}_2\text{Si}$  another signification. While G. Tammann‡ and W. Guertler consider that this compound solidifies in a crystalline form  $\text{Fe}_2\text{Si}$ , the author believes it to be a saturated mixing crystal, which

\* *Comptes Rendus*, vol. cxlviii. pp. 1767–1769.

† *Zeitschrift für anorganische Chemie*, vol. lix. p. 373; *Metallurgie*, vol. vi. pp. 92–93.

‡ *Zeitschrift für anorganische Chemie*, vol. xlvii. p. 163.

forms a eutectic with the compound  $\text{FeSi}$ . Thermal researches show that the crystallisation of all the iron-silicon-carbon alloys experimented upon takes place in one or in two intervals. The similarity which crystallisation of iron-silicon-carbon alloys displays with that of iron-carbon alloys is also observable in the transformations in the solid state. Either a formation of graphite takes place, or the silicon-martensite decomposes to silicon-ferrite and silicon-cementite.

J. Escard \* describes the properties of five definite silicides of iron—namely,  $\text{SiFe}_2$ ,  $\text{SiFe}_3$ ,  $\text{SiFe}$ ,  $\text{Si}_2\text{Fe}$ , and  $\text{Si}_3\text{Fe}$ , and traces the history of the production of commercial ferro-silicon by Berzelius, Valton, Pourcel, and Vers. It contains, as a rule, 10 to 15 per cent. of silicon and a considerable proportion of carbon. Only in the electric furnace is it possible to produce the alloy with a high silicon content. The Keller works at Livet make a product with 75 to 80 per cent. of silicon. The purest quartz is used, and coke with little or no phosphorus or sulphur, only sufficient carbon being used to reduce the iron and silicon. The higher the silicon content the more easily it is dissociated at high temperatures.

J. Escard † elsewhere states that the silico-manganese of commerce contains about 60 to 80 per cent. of manganese, and 20 to 25 per cent. of silicon, with varying percentages of carbon, iron, and aluminium. There are three definite silicides of manganese—namely,  $\text{SiMn}$ ,  $\text{Si}_2\text{Mn}$ , and  $\text{Si}_3\text{Mn}$ , the characteristics of which are given. In the manufacture of silico-manganese either rhodonite or mineral manganese dioxide (pyrolusite), or a mixture of both, is employed. The latter is usually used.

A. Portevin ‡ deals with the silicon alloys. The alloys described are silicon-aluminium, silicon-bismuth, silicon-calcium, silicon-cobalt, silicon-copper, silicon-magnesium, silicon-nickel, silicon-lead, silicon-antimony, silicon-tin, and silicon-thallium. In each instance he epitomises the researches of those investigators who have directed their researches to the elucidation of the chemical and physical properties of the alloys in question. Curves showing their constitution, and photomicrographs of the structures are given.

Particulars are given § of a silicon-calcium-aluminium alloy, the two chief applications of which are as an energetic deoxidiser, and for securing a better desulphurisation of steel. The composition is approximately 47 to 57 per cent. of silicon, 15 to 25 per cent. of calcium, and  $2\frac{1}{2}$  to  $6\frac{1}{2}$  per cent. of aluminium. This alloy is said to give better results than aluminium alone, even when it is added in the ingot mould itself, because it forms a very easily fusible slag which disengages from the steel. Added in the ladle it quiets the steel and enables sound ingots to be teemed.

P. Lebeau || has investigated the toxic gases evolved by ferro-silicon

\* *Lumière Electrique*, Série 2, vol. vi. pp. 301-306, 329-334.

† *L'Electricien*, vol. xxxvii. p. 293.

‡ *Revue de Métallurgie, Mémoires*, vol. vi. pp. 951-962.

§ *Electrochemical and Metallurgical Industry*, vol. vii. pp. 131-132.

|| *Revue de Métallurgie, Mémoires*, vol. vi. pp. 907-913.

under the influence of atmospheric moisture. On treating samples with water and collecting the resulting gases, with special precautions and refinements, it was found that a large quantity of hydrogen was present besides hydrogen phosphide ( $\text{PH}_3$ ) and arsenic hydride ( $\text{AsH}_3$ ). Some of the results were as follows :—

Samples.	Silicon per Cent.	H per Cent.	$\text{PH}_3$ per Cent.	$\text{AsH}_3$ per Cent.	Gas Evolved on Treatment.
					Cubic Centimetres per Kilogramme, or Litres per Ton.
1.	50	48.60	41.57	2.43	340.0
		to	to	to	to
		56.00	47.80	3.60	375.0
2.	50	1.00		17.55	47.4
		to	72.9	to	to
		9.47		27.10	52.0
4.	50	15.26	29.87	54.87	53.9

In no case was the gas thus obtained spontaneously inflammable. The experiments established the fact that with 50 per cent. silicon the gases from ferro-silicon are chiefly the three named, but that when the percentage of silicon exceeds 70, hydrogen arsenide becomes small, or *nil*. Micrographic examination reveals the fact that the impurities are evenly distributed throughout the mass of commercial ferro-silicon.

W. Fielding\* has investigated the conditions under which ferro-silicon can react with ferrous sulphide in the desulphurisation of iron and liberate a sulphide of silicon, and the reaction of the two compounds was investigated by heating intimate mixtures of them in a vacuum at known temperatures. The heating was effected in a crucible in the form of a hollow graphite rod heated electrically.

**Iron and Sulphur Alloys.**—Ziegler† has investigated the subject of alloys of iron with sulphur. In experimenting on such alloys it is necessary to avoid the presence of the impurities ordinarily present in commercial iron, such as carbon, silicon, manganese, and phosphorus, which may influence the result, and in order to obtain pure iron Goldschmidt's method was therefore resorted to. This consists of mixing the dried oxide ( $\text{Fe}_2\text{O}_3$ ) in a powdered state with aluminium powder. Certain precautions necessary to avoid contamination of the product by aluminium are described, and the various stages in the preparation of the oxide and in that of the powdered aluminium are detailed. In the subsequent experiments the method of intro-

\* *Transactions of the Faraday Society*, vol. v. pp. 110-112.

† *Revue de Métallurgie, Mémoires*, vol. vi. pp. 459-493.



ducing the sulphur is described. Alloys were made containing up to 6 per cent. of sulphur.

The first investigations were carried out, however, on commercial iron sulphide such as is used habitually in the preparation of hydrogen sulphide. The average percentage of sulphur is about 30, although the formula  $\text{FeS}$  requires 36.36 per cent. The percentage found corresponds with the following composition :—

	Per Cent.
Iron sulphide, $\text{FeS}$ . . . . .	82.5
Other bodies . . . . .	17.5
	<hr/> 100.0

The larger portion of these other bodies consists of metallic iron and iron oxides. G. Tammann\* and W. Treitschke, who have studied the thermal diagram of alloys of this series, have confirmed the conclusions of H. Le Chatelier and Ziegler, and show that no other compound is formed in this series. The percentage of sulphur corresponding with the eutectic is 30.91, which is but little higher than that of the iron sulphide of commerce. The latter represents, therefore, a hyper-eutectic alloy with an excess of iron. Thus, commercial sulphide of iron should reveal the presence of two constituents, the iron-sulphur eutectic forming the principal mass and an excess of iron in the form of crystallites. As a matter of fact, however, commercial sulphide of iron contains a third structure, a eutectic in which the sulphur is replaced by oxygen. This is the eutectic  $\text{FeO}$  with  $\text{Fe}$  which plays an important part in steels; an injurious form of oxide causing a burned condition occurs in steel in the form of this very eutectic. A photomicrograph showing the appearance of the various structures, some of which closely resemble the sorbite of steel, is given. On increasing the percentage of iron there will be observed a progressive increase in the quantity of iron in the crystallite form, and a corresponding diminution in the quantity of iron sulphide. No fresh structure is to be discerned. On solidification a portion of the iron crystallises in a dendritic form, and the rest in the form of a eutectic with the  $\text{FeS}$ . One of these alloys containing 22 per cent. of sulphur is illustrated by a photomicrograph. Its composition, assuming all the sulphur to be in combination as  $\text{FeS}$ , and that the rest is iron, would be as follows :—

	Per Cent.
Iron sulphide . . . . .	60.5
Iron . . . . .	39.5
	<hr/> 100.0

The quantity of iron in this alloy is seen to be double that in the preceding alloy. In the eutectic, owing to slow cooling, the structural constituents are sharply defined. Its appearance is contrasted with that of an alloy containing 14.193 per cent. of sulphur and certain proportions of carbon, silicon, manganese, and phosphorus. On a

\* *Zeitschrift für anorganische Chemie*, vol. xlix. p. 327.

micrographical examination it is found that with the foregoing composition the sulphur has caused a complete disappearance of the carbon, so that etching no longer reveals the presence of pearlite in the crystals of iron. It probably dissolves in the iron sulphide, as the carbide  $\text{Fe}_3\text{C}$  is soluble in that compound.

A third series of alloys was prepared containing an average of 6 per cent. of sulphur. Here, while the percentage of iron rises, the quantity of dendritic crystals also increases, but they tend to become indistinguishable when the sulphur percentage falls to 3.51 per cent. Other alloys containing respectively 0.9 per cent. of sulphur and 0.39 per cent. of sulphur were prepared and examined. The conclusions deduced from this portion of the investigations were as follows:—

The series of alloys starting from iron sulphide and ranging to iron containing only traces of sulphur really contains two structures alone, the iron-sulphur eutectic and metallic iron. A progressive increase in the quantity of iron crystals is observed in proportion as the percentage of sulphur diminishes. The space between the crystals is filled by the eutectic, composed of  $\text{FeS}$  and  $\text{Fe}$ , and also by another eutectic composed of iron-sulphur-oxygen, which reveals its presence as a greyish network, but possesses much less importance than the other. In these alloys the crystallites of iron are separated from each other by thin layers of the iron-sulphur eutectic. The complete structure is, however, so fine that it can only be completely resolved by the microscope when the samples have been cooled slowly.

The second portion of the investigation was directed upon the presence of sulphur in carburised iron. Given the preceding results obtained with the iron-sulphur alloys not containing carbon, it may be said, *a priori*, in regard to iron-carbon-sulphur alloys, that the character of the alloys should not change, and that no fresh constituents need be expected. As a matter of fact this is practically the case. The micrographic investigation of dead soft steel and of medium hard steel alike leads to conclusions similar to those arrived at in the case of iron-sulphur alloys containing traces only of carbon. To these conclusions has to be added the statement that iron sulphide is able to dissolve not only iron, but cementite as well, and—as a necessary consequence—the derivation of both, pearlite.

**Ferro Alloys.**—Chaplet \* describes the preparation and application of the more important ferro alloys used industrially in metallurgical operations, and indicates their purity and the nature of the brands currently obtainable in commerce. He includes in his classification ferro-silicon, ferro-chromium, and certain other alloys, and then deals with the pure metals themselves, which he classifies as follows:—

*Pure metals*—chromium, tungsten, molybdenum, vanadium, and titanium.

*Alloys.*—The above metals alloyed with iron or nickel, the latter including ferro-boron and nickel-boron.

\* *Revue de Métallurgie, Mémoires*, vol. vi. pp. 739-748.

*Special alloys*, including chromo-molybdenum, ferro-nickel-chromium, ferro-chromo-molybdenum, and ferro-nickel-chromium-tungsten; and

*Special deoxidisers*, such as ferro-silicon, ferro-silicon-aluminium, silico-aluminium, mangano-silicon, mangano-silico-aluminium, calcium-silicon, ferro-phosphorus, mangano-zinc, and aluminium-magnesium.

The special uses of each of these alloys, and the commercially obtainable brands, are described.

G. Gin,\* in discussing the manufacture of low carbon ferro alloys, remarks that it is well known that when fused carburised ferro-chromium is superheated in the presence of an oxidising slag and the entire mass is allowed to cool, it is regularly found that the surface of the previously tranquil bath on cooling down begins to boil, at first slightly, but with increasing intensity, up to the moment immediately preceding solidification. It is likely that this ebullition is caused by the disengagement of oxide and carbon due to deoxidation of the dissolved oxide by the carbon present in the alloy. It is very difficult to account for the cause of the phenomenon, but the author considers it is an example of the principle advanced by Le Chatelier that an increase of temperature favours endothermic reactions, while a lowering of temperature favours exothermic reactions.

The chemical properties and use of ferro-tungsten powder are described.† Ferro-tungsten is an intimate combination of iron and tungsten, the microscope, and magnetic methods alike failing to reveal any separate constituents as being present. It has the following composition:—

	Per Cent.
Tungsten . . . . .	85·00
Carbon . . . . .	0·3
Silicon . . . . .	0·45
Manganese . . . . .	0·45
Aluminium, calcium, and magnesia . . . . .	0·25
Sulphur . . . . .	0·01

The remainder is, presumably, iron. It can be employed economically in the production of special steels, as very little passes into the slag, on addition to the molten metal.

G. Surr ‡ reviews the present knowledge of the influence of manganese, nickel, chromium, tungsten, molybdenum, titanium, and vanadium, when alloyed with iron and steel.

**Chromium - iron Alloys.**—F. Cirkel§ gives an account of chromium-steel alloys, their uses and properties.

**Production of Chromium.**—Solid chromium is now obtained || commercially in two ways: (1) By the thermite method; (2) by

\* Paper read before the American Electrochemical Society; *Mining World*, vol. xxxi. p. 322.

† *Iron Age*, vol. lxxxiv. p. 629.

‡ *Mining World*, vol. xxx. pp. 1162-1164.

§ *Canada, Department of Mines*, Ottawa.

|| *Brass World*, vol. v. pp. 173-174; *Engineering and Mining Journal*, vol. lxxxvii. p. 1129.

means of the electric furnace. The thermite process consists in reducing the oxide of chromium by means of aluminium. The reaction which takes place supplies the heat necessary to melt the chromium, and by adjusting the proportion of oxide of chromium and aluminium it is possible to obtain fused metallic chromium of high purity, free from carbon. In the electric furnace oxide of chromium is heated with carbon by means of the electric arc and the chromium is then reduced to a metallic state. When thus made it is combined with a large percentage of carbon, and requires purification. To remove the carbon, the crude chromium is melted with lime in an electric furnace. The carbon combines with the calcium to form calcium carbide, and the pure chromium is obtained as a fused mass.

**Nickel-iron Alloys.**—E. Guilleaume\* points out that though nickel steels were made as far back as 1820, it is only recently that nickel-iron alloys high in nickel have come into general use. The irregularities of the coefficient of expansion have been carefully studied. When the percentage of nickel is 22 to 28 this coefficient is greater than the laws of alloys would predict. With 28 to 80 per cent. of nickel it is smaller, and from 80 per cent. upwards it is normal. In "invar" metal with a nickel content of 36 per cent. the value is reduced to 0.1 that of iron, and by proper treatment may be made to correspond with the normal theoretical coefficient. This alloy is tough, easily worked, and only slightly oxidisable, and on account of these properties is especially applicable to the manufacture of scientific instruments.

**Tantalum-iron Alloys.**—Details have been published† of an investigation of tantalum steels, carried out by G. G. Blackwell, Sons & Co. A series of experiments with the direct use of tantalum in steel of various percentages of carbon appeared to prove that tantalum was a hardening metal similar to tungsten and molybdenum. Particulars are given of the composition, elastic limit, ultimate stress, elongation, and reduction of area of tantalum steel.

A. Siemens‡ has delivered a lecture on tantalum and its industrial applications. Tantalum is now known to be a ductile metal of a density of 16.6, resembling steel. The chief sources of tantalum ore are Scandinavia, South-West Africa, Western Australia, and North America, where it occurs in the form of columbite containing up to 40 per cent. of titanate pentoxide and a good deal of niobium, combined with iron and manganese. Another form often met with is tantalite, the pentoxide combined with iron and manganese.

Tantalum has three-quarters the heat conductivity of iron and one-eighth that of copper. At ordinary temperatures and up to

\* *L'Électricien*, vol. xxxviii. p. 55.

† *Iron and Coal Trades Review*, vol. lxxviii. pp. 933-934.

‡ Lecture delivered before the Royal Institution, April 23, 1909; *Engineering*, vol. lxxxvii. pp. 601-602.

about 300° C. it resists all acids except hydrofluoric acid, as well as alkalis and moisture, and is an ideal metal for chemical apparatus. It is as elastic and hard as soft steel, and can be hammered, stamped, and drawn into fine wire. The tensile strength is 57 tons per square inch. Some of these good properties disappear when the metal is heated. It then absorbs gases, notably hydrogen and nitrogen, and becomes brittle. The melting point lies between 2250° and 2300° C., and the metal therefore makes excellent electrodes for Röntgen tubes. The tantalum filaments employed for lamps have a diameter of 0.3 millimetre, and 1 kilogramme of tantalum will furnish sufficient filament for over 45,000 lamps.

**Uranium-iron Alloys.**—Uranium, which is distinguished chemically on account of having the highest atomic weight (238) of any known element, has considerably increased of late in value as a metallurgical product. It increases the hardness, toughness, and elasticity of steel when alloyed with this material, though not to the same extent as vanadium, chromium, nickel, and tungsten. For ordnance and armour plate, however, uranium steel is specially well adapted.\*

**Vanadium-iron Alloys.**—G. Gin † states that he has obtained the silicide  $\text{SiV}_2$  by reducing in an electric furnace a mixture of vanadic acid, silica, and coke according to the equation,  $3\text{V}_2\text{O}_5 + \text{SiO}_2 + 13\text{C} = 2\text{V}_2\text{O}_3 + \text{SiV}_2 + 13\text{CO}$ . The manufacture of the double silicide of iron and vanadium is more easily accomplished than that of the silicide of vanadium, when reducing vanadium trioxide by means of rich ferro-silicon. The brittle 60 per cent. ferro-silicon is powdered and mixed intimately with vanadium trioxide. This is agglomerated with 4 to 6 per cent. of coal-tar pitch, and moulded into briquettes or oval balls, which are charged into a double-hearth furnace with a rammed magnesite bottom. Reduction takes place according to the formula,  $4\text{V}_2\text{O}_5 + 4\text{FeSi}_2 + 5\text{C} = \text{Fe}_4\text{Si}_3\text{V}_6 + \text{V}_2\text{O}_3 + 2\text{SiO}_2 + 5\text{CO}$ . Vanadium silicide, or the double silicide of iron and vanadium, may also be produced in the electric furnace by the reaction of trioxide or tetroxide of vanadium with carborundum, or of a mixture of carborundum with rich ferro-silicon.

W. L. Morrison ‡ describes laboratory methods for making alloys of iron and vanadium. Binary alloys of pure iron and vanadium, free from carbon, can be conveniently made by two methods: (1) Goldschmidt's method, using pure aluminium and hammer scale from puddled iron, and mixing a little ferro-vanadium with the charge; (2) by the use of an electric resistance furnace, having a crucible in the resistor to melt puddled iron and ferro-vanadium.

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lviii. pp. 313-315.

† Paper read before the American Electrochemical Society, May 1909; *Electrochemical and Metallurgical Industry*, vol. vii. p. 264.

‡ *Engineering and Mining Journal*, vol. lxxxvii. p. 1035.

**Steel Alloys for Motor-car Construction.**—J. A. Mathews \* describes the types of alloy steels in general use for motor-car construction, and deals with heat treatment, the merits of case-hardened *versus* oil-hardened gears, and drop-forged gears *versus* gears cut from the bar. In an appendix tables are given showing typical analyses, treatments, and tensile tests of nickel, nickel-vanadium, chromium-nickel, and chromium-vanadium steels.

Results have been published † of a series of tests carried out on motor-car steel. One of the materials used was a high tenacity nickel-chromium steel for crank-shafts and connecting-rods, the particular mechanical properties being secured by suitable heat treatment.

**Monel Metal.**—D. H. Browne ‡ gives a brief description of the characteristics and composition of Monel metal. Like steel, this alloy absorbs carbon, and its properties are profoundly influenced not only by the percentages of carbon and silicon it contains, but by the heat treatment it receives. A standard analysis of Monel metal is as follows :—

	Per Cent.
Nickel . . . . .	68.0 to 72.0
Iron . . . . .	0.5 to 1.5
Sulphur . . . . .	0.014
Carbon . . . . .	0.073 to 0.15
Copper to balance.	

C. S. Dunbar § states that among the newer alloys Monel metal has attracted particular interest on account of its high tensile strength combined with easy machining qualities and its high resistance to corrosive action and fatigue strains. The physical properties of the alloy are compared with those of manganese bronze and nickel steel, the following being the results of tests :—

	Manganese Bronze.	Monel Metal.	Nickel Steel.
Elastic limit per square inch . . . .	46,200 lbs.	76,500 lbs.	81,000 lbs.
Maximum strength per square inch . .	80,600 lbs.	105,500 lbs.	107,700 lbs.
Elongation in 2 inches . . . . .	26.0 per cent.	19.5 per cent.	21.5 per cent.

A. Stansfield || describes the process of manufacture of Monel metal. A table is given showing its mechanical properties. The cast metal has an ultimate tensile strength of 65,000 to 85,000 lbs. per square

\* *Journal of the Franklin Institute*, vol. clxvii. pp. 379-397.

† *Iron and Coal Trades Review*, vol. lxxix. p. 240.

‡ *Mining World*, vol. xxx. p. 470.

§ *Metal Industry*, vol. i. p. 43.

|| *Canadian Society of Civil Engineers, Bulletin No. 5*, pp. 92-110.

inch, and an elongation of 10 to 30 per cent., while the rolled metal has an ultimate strength of 90,000 to 110,000 lbs., and an elongation of 25 to 30 per cent.

W. E. D. Wilkes\* gives a brief description of the properties of Monel metal, and gives a table showing the comparative results of tests on this metal, steel, and copper.

**Production of Electrolytic Iron.**—A. Müller† deals with the preparation and composition of electrolytic iron, and the production of the material in large quantities, in the shortest time possible, free from silicon, phosphorus, sulphur, manganese, and carbon. To reduce the percentage of carbon the anode should be as pure as possible, protected by a porous cell, emptied daily and replaced by a new solution. The anode should be frequently cleaned by brushing away the dirt with dilute hydrochloric acid, and the electrolyte should be free from carbon. Sulphur should be subsequently removed by refining. A vacuum furnace for investigating thermal properties is described. The crucible is charged with 70 grammes of iron, and a temperature of about 1700° C. can be attained in twenty minutes. Numerous references are given to the investigations of other workers.

**Corrosion of Iron and Steel.**—A. Schleicher‡ deals at length with the differences in the tendency of various qualities of iron to rust. A list of the most important memoirs dealing with the subject-matter of the paper is appended.

A. A. Knudson§ deals with the electrolytic corrosion of pipes underground due to stray currents. The most destructive effect of electrolysis is shown where the current passes from a water main to another conductor, resulting in the well-known "pitting" and eventual perforation of the metal, but damage is also caused to the joints of the pipes by the current passing along them, the inside of the joint being chiefly affected by the electrolytic action. The author illustrates and describes a number of cases of corrosion, and considers that the only remedy lies in a non-grounded return of the current. Water meters are said to be particularly subject to the effect of electrolytic action.

The experiments of W. A. Tilden, J. A. N. Friend, Haldane Gee, E. Heyn, O. Bauer, and others, with regard to the corrosion of iron, are discussed in detail, the various theories advanced are criticised, and their bearing on the practical side of the problem is investigated.||

W. R. Mott¶ discusses "overvoltage" as a factor in the corrosion of metals.

W. H. Walker\*\* deals with the corrosion of zinc-plated iron wire, and the corrosion of tubes and shells of steam boilers.

\* *Canadian Machinery*, May 1909, pp. 41-42.

† *Metallurgie*, vol. vi, pp. 145-160.

‡ *Ibid.*, pp. 182-190, 201-214.

§ *Journal of the Franklin Institute*, vol. clxviii, pp. 132-152.

|| *Engineering*, vol. lxxxviii, pp. 272-274.

¶ Paper read before the American Electrochemical Society, May 1909; *Electrochemical and Metallurgical Industry*, vol. viii, p. 280.

\*\* *Ibid.*, vol. vii, pp. 150-151.

J. C. W. Greth\* deals with the various substances which cause scale and corrosion in boilers. The different methods for the prevention and removal of scale are considered, and the author concludes with an argument in favour of purifying and softening the feed water before it is put into the boiler.

With a view to the prevention of rust in boilers, experiments were carried out at the Berlin Technical Institute with water which had been freed from the air it contained by means of charcoal. The decrease of rust in the boilers fed with water thus treated was about 25 per cent.†

The rusting of steel partially embedded in concrete is shown by the following example of a small iron bolt, one of many used for holding down the rails of a railway on a foreshore.‡ The bolt was  $6\frac{1}{2}$  inches long, and embedded in a concrete block to the depth of 4 inches. On removal it was found that the head and about 1 inch of the shank were quite free from rust. The shank tapered to the surface of the concrete, at which spot the bolt had suffered most, and the projecting part, besides being rusted, had suffered from the grinding action of the shingle. The rust had evidently spread from the surface of the concrete, gradually diminishing until at a depth of 3 inches the bolt was quite unaffected.

**Prevention of Rust.**—C. Coffignier§ deals with paints used for the protection of surfaces exposed to sea-water, and vitreous paints requiring fusion for their application, and gives a brief historical account of their origin and development, together with analyses and recipes for various compositions, the uses of which are advocated.

According to M. Toch,|| there is, after a lapse of six months, no difference in the extent of corrosion of steel which has been coated with a good protective paint and steel which has been first rendered passive by means of a chromate and then coated with a similar paint. The corrosion is greatest where two pieces of steel come in contact, and it is recommended that such places be covered with an alkaline or an electrically insulating paint.

R. B. Harper¶ deals with the comparative values of various coatings and coverings for the prevention of corrosion of iron pipe, and, as the result of numerous tests carried out with various paints, he concludes that paints as a rule do not prevent electrolysis, although some are beneficial in restraining corrosion by the action of the soil.

The report of the Committee of the Master Car Builders' Association on time tests of preservative coatings on steel cars has been published.\*\*

\* Paper read before the Scranton Engineers' Club, May 20, 1909; *Power*, vol. xxx. pp. 1091-1092.

† *Petroleum Review*, vol. xx. p. 254.

‡ *Engineer*, vol. cvii. p. 628.

§ *Revue de Métallurgie, Mémoires*, vol. vi. pp. 734-738.

|| *Transactions of the American Electrochemical Society*, vol. xiv. pp. 207-213.

¶ Pamphlet published by the Illinois Gas Association; *Ironmonger*, vol. cxxviii. p. 317.

\*\* *Engineering News*, vol. lxii. pp. 20-21.



S. A. Tucker \* and E. G. Thomassen deal with the electrolytic deposition of lead and zinc. They refer to a patent of Classen, according to which deposits of zinc can be much improved by the addition to the electrolyte of liquorice root, or an extract of some other similar organic compounds.

H. E. Patten † and W. R. Mott deal with the electro deposition of some metals from acetone solutions.

A. Sang ‡ describes the various oxidation processes which have been introduced for the protection of iron and steel.

It is stated § that the addition of about 5 per cent. of quicklime to sour, soggy clays and soils will, in a large degree, prevent the corrosion of embedded iron or steel.

A remarkable instance ¶ of the manner in which iron is preserved when embedded in cement was recently manifested on the occasion of the demolition of an old gasometer in Hamburg, built in 1852-55. On the removal of the foundation piers by blasting, the iron anchor-bolts of the superstructure were laid bare. In all sixty of these were discovered, 2 x 2 inches square, and 6 to 9 feet in length, and without exception all were in a perfect state of preservation, showing a steel-blue skin as fresh as on leaving the rolls, and without a spot of rust. The bolts were embedded in a solid cement covering  $\frac{3}{4}$  inch thick, which appeared to have been run in round them at the time of placing them in position, and there is no doubt that the bars have thus been preserved for upwards of fifty years.

Rohland ¶ traces the cause of the disappearance of rust from iron bars used in the erection of ferro-concrete to the presence of acid carbonates and sulphates in the cement, these salts dissolving the iron oxide, and leaving the metal bright.

\* Paper read before the American Electrochemical Society, May 1909; *Electrochemical and Metallurgical Industry*, vol. vii. p. 273.

† *Ibid.*

‡ *Electrochemical and Metallurgical Industry*, vol. vii. pp. 351-353.

§ *Iron and Steel Trades Journal*, vol. lxxxv. p. 89.

¶ *Zement und Beton*, 1908, No. 48; *Zeitschrift des oesterreichischen Ingenieur- und Architekten Vereines*, vol. lxi. p. 175.

¶ *Stahl und Eisen*, vol. xxix. pp. 408-409.

# CHEMICAL ANALYSIS.

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### I.—ANALYSIS OF IRON AND STEEL.

**Determination of Carbon.**—W. L. Keeler\* describes a method of determining carbon in steel by means of a direct combustion apparatus. A distinctive feature of the process is the position of the copper oxide. In most direct combustion trains the copper oxide is placed either in the main tube in the furnace, or entirely outside the combustion tube in a small porcelain tube. In the present method the copper oxide, in the form of an oxidised coil made from copper gauze, is placed in the main combustion tube, but at the extreme left end and outside the furnace, where it is kept at a dull red heat by an ordinary bunsen burner.

F. C. T. Daniels† describes a method for the direct combustion of carbon in steel, which it is claimed can be carried out in from fifteen to twenty-five minutes. The direct combustion can be made in a porcelain tube, and the method is adaptable to a small laboratory, where it is not advisable to purchase the ordinary platinum apparatus or an electrical furnace.

A. F. Shore‡ describes a method of determining the carbon, phosphorus, manganese, and tungsten in steel, with the aid of the scleroscope.

H. P. Mason§ gives in detail methods for the determination of manganese, carbon, silicon, sulphur, phosphorus, titanium, and vanadium. A complete analysis of No. 3 Derbyshire pig iron is also given.

E. Goutal|| describes the gases disengaged by the action of an acid solution of double chloride of copper and potassium on three specimens of steel with 0.29, 0.64, and 1.38 per cent. of carbon respectively.

\* *Iron Age*, vol. lxxiv. pp. 260-262.

† *Iron Trade Review*, vol. xlv. pp. 215-217.

‡ *American Machinist*, vol. xxxii. pp. 1066-1069.

§ Paper read before the British Foundrymen's Association; *Foundry Trade Journal* vol. xi. pp. 292-295.

|| *Comptes Rendus*; *Nature*, vol. xxx. p. 239.

**Determination of Phosphorus.**—The determination of phosphorus in iron and steel is described by G. Chesneau.\*

**Determination of Sulphur.**—In discussing the report of the American Foundrymen's Association on standard specifications, E. A. Kebler† takes exception to the requirement that the gravimetric method be used for sulphur. The adoption of this method is a most serious change from the usual practice, the volumetric method being in general use in foundries. The gravimetric method should not, it is suggested, be adopted as a standard until foundrymen are willing to receive an ostensibly higher sulphur content than is specified in their contract.

**Determination of Chromium.**—P. Fischbach‡ describes a method for the quick and accurate determination of small amounts of chromium in iron and steel, in which the preliminary laborious precipitation of the iron is avoided, and a higher degree of accuracy is obtained by titration. The method of procedure is as follows: 5 to 10 grammes are dissolved in hydrochloric acid, filtered, and reduced with zinc. A thin paste of oxide of zinc and water is added to slight excess, with constant stirring. This is heated just to boiling, allowed to settle, and filtered. If the excess of zinc oxide is somewhat large, the residue is dissolved from the filter with dilute hydrochloric acid, reduced with zinc and again precipitated, filtered, and washed well with hot water, dried, and the residue ignited in a porcelain crucible. The crucible content is intimately mixed with two parts of sodium carbonate and three parts of manganous oxide, and heated in an open muffle for about one hour. The mass is dissolved in hot water, filtered, allowed to cool, and 1 cubic centimetre of potassium iodide solution (1 : 15) is added. The mixture is weakly acidulated with hydrochloric acid, allowed to stand a few minutes with frequent shaking, and titrated with sodium thiosulphate.

**Determination of Nickel.**—Prettner-Spandau§ has carried out a full investigation as to the respective merits of the electrolytic process of estimating nickel in nickel steels, and the processes recommended by Brunck and Grossmann. The author favours the latter's method, particularly when cobalt is present in some quantity, and where the direct cyanide-titration process cannot be applied.

**Determination of Tungsten.**—M. Tschilikin|| states that tungsten can be determined by means of  $\alpha$ -naphthylamine, and that the method gives good results. The compound formed has the formula

\* Paper read before the Seventh International Congress of Applied Chemistry, London.

† *Foundry Trade Journal*, vol. xi. pp. 399-400.

‡ *Stahl und Eisen*, vol. xxix. pp. 248-249.

§ *Chemiker Zeitung*, vol. xxxiii. pp. 396, 411-412.

|| *Berichte*, vol. xlii. No. 6; *Chemical News*, vol. xcix. p. 300.

$2(\text{C}_{10}\text{H}_9\text{N}) \cdot 5\text{WO}_3 \cdot 3\text{H}_2\text{O}$ , and the reaction takes place at the ordinary temperature. From results of analyses carried out by this method, the author has found that commercial sodium tungstate has the formula  $\text{Na}_2\text{WO}_4 + 2\text{H}_2\text{O}$ .

H. Bartonec\* describes a method for the determination of tungsten in tungsten steel. It is claimed that the method described gives higher but more accurate results than other methods.

**Detection of Molybdenum and Vanadium.**—J. Pepin-Lehalleur† discusses the methods proposed by A. A. Blair‡ for the analysis of special steels, and describes those which he has found most satisfactory in practice. Tests for the qualitative determination of molybdenum and of vanadium in the presence of chromium are also given.

## II.—ANALYSIS OF IRON ORES AND SLAGS.

**Modern Practice in Ore Sampling.**—D. W. Brunton§ deals with modern methods for the sampling of ores, and points out that samples for the determination of moisture should be taken with as much care as those for the determination of metallic contents. What is known as Cornish quartering was at one time the almost universal method of sampling, and is still employed to a considerable extent in cutting down machine samples and in other instances. When properly carried on with skill, care, and common honesty, fairly good results may be obtained; but it affords many opportunities for error, its inherent difficulty being that piling a heap of ore in the form of a cone does not really mix it, but may actually produce a very perceptible sorting action, as the fines build up where they fall on the centre of the cone, and the coarser particles roll outward and down the sides causing irregularities in the mass that subsequent operations fail to rectify. The method by which unprincipled samplers succeed in vitiating the results is what is known as “drawing the centre,” whereby the apex of the cone, which with the portion of the mass immediately below it contains the largest proportion of fines, is slowly altered until it no longer marks the centre of the heap, when the subsequent halving and quartering may result in two of the quarters containing a highly undue proportion of fines or coarse, as the case may be. Methods of mechanical sampling are then described, and practical results obtained in their use given in tabular form. The need for a standardisation of methods of sampling in mining and metallurgical industries is emphasised, both from a business and from a scientific point of view.

\* *Oesterreichische Chemiker-Zeitung*, vol. xii. pp. 114-115.

† *Moniteur Scientifique*, vol. xxiii. pp. 263-264.

‡ *Journal of the Society of Chemical Industry*, vol. xxvii. p. 902.

§ *Bulletin of the American Institute of Mining Engineers*, 1909, pp. 675-704.

**Definition of Ore.**—J. F. Kemp \* discusses at some length the question, What is an ore? Various definitions are quoted and examples submitted.

**Iron Ore Analysis.**—L. Campredon † describes the Rothe process for the analysis of iron ores, as modified and improved by Carnot. It is based on the fact that the addition of ether to a hydrochloric acid solution of iron and other metals dissolves the iron chloride and leaves the other metals in the acid solution. The convenience of thus removing, by a simple operation, all, or at least most of the iron, which hampers and interferes with the processes of separation usually adopted, will be readily appreciated by chemists. The process can be conducted as follows: 10 grammes of the ore are treated, in a covered flask, with 80 cubic centimetres of strong hydrochloric acid and 20 cubic centimetres of strong nitric acid. On complete solution the liquid is transferred to a porcelain basin and evaporated to dryness, taken up with hydrochloric acid and filtered. In the siliceous residue remaining, silica, combined alumina, lime, magnesia, barium sulphate, and alkalis can be determined. The filtrate contains all the elements soluble in aqua-regia. It is again evaporated to dryness, taken up with 60 cubic centimetres of strong hydrochloric acid, and transferred to a separator, where 100 cubic centimetres of ether are added, with the usual precautions. There is thus obtained a ferruginous ethereal liquor, which is disregarded, and an aqueous solution containing all the elements which it is required to estimate. The latter is warmed, to expel the associated ether, and made up to 200 cubic centimetres. Of this 100 cubic centimetres are reduced by bisulphate and a current of sulphuretted hydrogen passed. The precipitated sulphides are collected, washed, and treated on the filter by a 1:20 solution of potassium hydrate in order to separate the arsenic and antimony from the lead and copper. The filtrate from the sulphides contains any remaining iron, and the manganese, aluminium, chromium, zinc, nickel, and lime and magnesia. The methods of separating the various constituents are indicated briefly.

**Determination of Iron.**—J. S. MacLaurin ‡ and W. Donovan describe a rapid and accurate method of estimating iron in iron ores. It is claimed that by the method described the difficulty of getting the iron into solution within a reasonable time in the estimation of iron in magnetites and hæmatites is entirely removed. The process gives very constant results, duplicate determinations agreeing excellently, and consists briefly of the following steps: (1) roasting the finely ground ore; (2) reduction of the roasted ore by heating in coal gas or hydrogen; (3) solution of the reduced ore in dilute sulphuric acid in

\* Paper read before the Canadian Mining Institute; *Mining World*, vol. xxx. pp. 1111-1114.

† *Revue de Métallurgie, Mémoires*, vol. vi. pp. 826-828.

‡ *Journal of the Society of Chemical Industry*, vol. xxviii. pp. 827-828.

an atmosphere of carbon dioxide; (4) titration of the resulting solution by potassium permanganate. The advantages of the process over those commonly employed are the removal of any organic matter which might interfere with the subsequent titration, the ease and completeness with which the ores are dissolved, the accuracy of the titrations, and the possibility of estimating titanium in the same solution.

J. A. N. Friend \* draws attention to the fact that the rate at which permanganate is added to the ferrous solution in the determination of iron in the presence of hydrogen chloride greatly affects the value of the titration. It is suggested that the reaction takes place in two stages. First there is a partial reduction resulting in the oxidation of some of the iron, and the formation of an unstable perchloride of manganese. The latter substance then oxidises the ferrous iron until equilibrium is established. If the directions given are rigidly adhered to fairly accurate estimations of iron may be obtained in the presence of hydrochloric acid.

R. K. Mead † gives tables for making up standard solutions of potassium permanganate and potassium bichromate for determining iron in ores. He then describes the following three methods for the determination of iron:—

*Marquerite's Method.*—Grind the ore finely in an agate mortar; dry on a watch glass in an air-bath for one hour at a temperature of from 100 to 110° C.; pour into a test-tube, and keep tightly corked. When cold weigh from 0.5 to 1 gramme of the ore into a No. 3 beaker; add 20 cubic centimetres of strong hydrochloric acid, cover with a watch glass, and heat on the hot plate. Do not boil, since ferric chloride is likely to volatilise if the solution is heated to a boiling point. When the ore is fully decomposed and only a white residue remains, remove the beaker from the hot plate, cool, and add 30 cubic centimetres of dilute sulphuric acid. Evaporate until white fumes begin to come off. Remove from the plate, cool, and add 75 cubic centimetres of water. Heat until soluble salts are in solution and filter, washing the filter-paper with water. Transfer the residue to a small platinum crucible to cool, pour upon the contents from 15 to 40 drops of sulphuric acid and twice as much hydrofluoric acid. Heat carefully until the residue is dissolved, evaporate off all the hydrofluoric acid, cool, dilute, and add the solution to the filtrate. Cool the combined solutions, and after adding 10 cubic centimetres of sulphuric acid, pass through the reductor. Add 5 cubic centimetres of dilute sulphuric acid, and titrate the solution with permanganate.

*Penny's Method.*—Weigh from 0.5 to 1.0 gramme of the ore into a small dry beaker and add 15 to 20 cubic centimetres of concentrated hydrochloric acid. Cover with a watch glass and heat on the hot plate, at a temperature just short of boiling, until all the iron is dissolved. Dilute to 40 to 50 cubic centimetres and digest on the hot

\* *Proceedings of the Chemical Society*, vol. xxv. pp. 150–151.

† *Mining World*, vol. xxx. pp. 569–572.

plate for a few minutes. Filter through a 9 cubic centimetre filter and wash the latter free from iron with cold water. Place the filtrate on the hot plate and heat to boiling. Drop in stannous chloride solution, drop by drop, until the solution is colourless. Add a drop or two in excess. Cool the solution by placing in cold water, and when perfectly cold add 15 cubic centimetres of mercuric chloride solution and stir well. Let stand a minute or so. A white precipitate should form. If no precipitate forms, insufficient stannous chloride was added. If a black precipitate appears, too much stannous chloride was used. In either event the analysis should be repeated. Titrate with standard bichromate solution.

*Lake Superior Method.*—Weigh 0.5 gramme of the ore into a porcelain dish and add a slight excess of stannous chloride solution and 10 to 15 cubic centimetres of hydrochloric acid (1.1). Boil gently until the iron is all dissolved. This point may be recognised by the light colour of the solution, the stannous chloride reducing the iron. Unless slightly yellow in colour, add a little permanganate solution until the excess stannous chloride is destroyed, and then add stannous chloride, drop by drop, until the solution is colourless. Add 5 cubic centimetres of mercuric chloride solution and dilute at once to 250 cubic centimetres with cold water. Now add 5 to 10 cubic centimetres of the "titrating mixture" and titrate with standard permanganate. The "titrating mixture" is made by dissolving 90 grammes of manganous sulphate in water, diluting to 650 cubic centimetres and adding 175 cubic centimetres of sulphuric acid (1.84 specific gravity), and then 175 cubic centimetres of "syrupy" phosphoric acid (1.725 specific gravity). The mercuric chloride solution is a saturated solution of the salt.

For the determination of ferrous oxide in magnetite R. B. Gage\* describes the following method: Half a gramme of the sample is weighed into a 50 cubic centimetre platinum crucible. It should be thoroughly moistened with water, and a couple of platinum wires added to prevent bumping. A cold mixture of 10 cubic centimetres of hydrofluoric acid and 15 of dilute sulphuric acid (1 : 3) is added, and the crucible is quickly covered. A 6-inch funnel, the top of which is connected with a carbon dioxide generator and the inside coated with paraffin, is placed over the crucible. After the air has been expelled from the funnel a Bunsen burner is placed beneath the crucible, and the liquid is allowed to boil gently for a few minutes. An ordinary rock can usually be decomposed in five minutes, while magnetites and rocks rich in ferro-magnesian minerals may take a little longer. After the sample is decomposed the crucible is plunged at once into a beaker containing 400 to 500 cubic centimetres of cool, boiled, distilled water. The contents are quickly mixed with the cold water, and a solution containing the required amount of calcium phosphate is added, and titration made as rapidly as possible. The first permanent colour is taken for the end point.

\* *Journal of the American Chemical Society*, vol. xxxi. pp. 381-385.

G. C. Jones \* and J. H. Jeffery record their experiments in connection with the estimation of iron by permanganate in the presence of hydrochloric acid.

W. C. Dumas † compares the methods for the determination of iron and alumina in the presence of phosphoric acid and lime.

**Determination of Arsenic.**—A. Grabe ‡ and J. Petró review the different methods of determining arsenic in iron ore and iron.

**Determination of Cobalt.**—C. D. Test § gives a method for the volumetric estimation of cobalt based on the separation of that element from nickel as a double potassium cobaltic nitrite, with subsequent decomposition of the nitrite with sulphuric acid, and titration of the liberated nitrous acid with potassium permanganate. The precautions necessary to secure accurate results are detailed, and the cobalt factor of permanganate is given as equal to the iron factor multiplied by 0·0877 in a solution of approximately 10 grammes of permanganate to the litre.

**Determination of Molybdenum.**—W. Trautmann || gives a method for the ready determination of molybdenum in molybdenite.

**Determination of Tungsten.**—H. W. Hutchin ¶ and F. J. Tonks give the three methods in general use for the determination of tungstic acid in low-grade ores, and describe a new method, which is stated to be more speedy and accurate.

**Determination of Vanadium.**—H. Fleck \*\* quotes the following as a method for analysis of vanadium. Fuse 1 gramme of finely divided ore with sodium carbonate in a platinum crucible. Extract with hot water. Filter and wash with hot water. Repeat fusion on residue if necessary. Acidify filtrates with sulphuric acid, heat nearly to boiling, reduce with sulphurous acid, boil off excess, and titrate the solution with permanganate standard solution. On these samples the use of hydrogen sulphide is omitted, as arsenic and molybdenum are absent.

**Determination of Vanadium and Arsenic.**—In view of the almost constant association of arsenic and vanadium in the mineral sources of both elements, G. Edgar †† has devised a method for the

\* *Analyst*, July 1909; *Chemical News*, vol. c. pp. 164-165, 177-180.

† *Chemical Engineer*, vol. ix. p. 107.

‡ *Jernkontorets Annaler*, vol. lxiv. pp. 97-117.

§ *Western Chemist and Metallurgist*, vol. iv. pp. 167-173; *Engineering and Mining Journal*, vol. lxxxviii. p. 256.

|| *Chemiker Zeitung*, vol. xxxiii. pp. 1106-1107.

¶ *Bulletin of the Institution of Mining and Metallurgy*, No. 56.

\*\* *Mining World*, vol. xxx. pp. 596-598.

†† *American Journal of Science*, vol. xxvii. pp. 299-301.



determination of these elements in the presence of each other by a process of differential reduction.

**Determination of Vanadium, Chromium, and Iron.**—G. Edgar \* also describes a method that has been worked out for the iodometric estimation of vanadic acid, chromic acid, and iron in the presence of one another. The control analyses show that the process is highly accurate.

**Detection of Tungsten, Molybdenum, and Vanadium.**—G. Surr † describes the following simple methods of testing ore for tungsten, molybdenum, and vanadium.

Tungsten, is readily detected, provided that the mineral, especially if it be dark in colour, be first ground to a very fine powder. Pour into a test-tube, say, half an inch in diameter, enough of the fine powder to cover the bottom to a depth of about half an inch, add three or four times as much strong hydrochloric acid, and boil gently over the spirit-lamp for a few minutes. Two or three minutes is usually enough for scheelite, but hübnerite may require boiling for ten minutes before sufficiently decomposed. Decomposition has gone far enough when the tube becomes more or less coated with a yellowish film, or when a yellow or olive-green powder separates out. Now drop in a piece of pure tin-foil, as big, when tightly folded, as a pea; heat again, and if the sample be a tungsten mineral, the solution will become a beautiful deep-blue colour. Continue to boil, and the blue will change to dark-brown, should enough tin and acid be present.

Molybdenum may be detected by evaporating the powdered mineral to dryness in a porcelain basin, with three or four times its bulk of strong nitric acid, then heating to boiling with two or three volumes of hydrochloric acid, when the addition of a piece of pure tin-foil, and further warming, causes the solution to become green, and finally brown, if molybdenum be present.

Vanadium minerals may be sufficiently decomposed for testing by warming the fine powder for a few minutes with nitric acid over an alcohol lamp, preferably in a porcelain basin. About six volumes of dilute nitric acid, half acid and half water, will generally answer the purpose, unless the substance be difficult to decompose, when a longer application of a gentle heat, and more of the dilute acid may be required. After the acid seems to have no more effect, and red fumes cease to come off, the solution is diluted with one or two volumes of water, brought to a boil, and set aside to clear. Settling may often be assisted by pouring some of the liquid into a clean test-tube. When fairly clear, add a little hydrogen peroxide, and if vanadium be present, the solution will immediately become reddish brown.

G. S. Holloway ‡ deals with the detection and estimation of rare

\* *American Journal of Science*, vol. xxvii. pp. 174-178.

† *Mining World*, vol. xxxi. pp. 369-370.

‡ Paper read before the Seventh International Congress of Applied Chemistry, London.

metals in minerals, particularly of such as are used in the manufacture of special steels.

**Determination of Sulphur in Fluorspar.**—A method for the estimation of barium sulphate in commercial fluorspar is described by H. G. Martin.\* It is based on the fusion process with sodium peroxide recommended by S. W. Parr,† using a Sundström bomb for the combustion and oxidation. The process is a rapid one of the rough and ready kind, but will, it is claimed, give good results in the detection of what, in open-hearth practice, is often the bane of the furnace manager.

### III.—ANALYSIS OF FUEL.

**Sampling of Coal for Analysis.**—E. G. Bailey ‡ discusses the question of accuracy in sampling coal. The most important factor to be considered in sampling coal is the “size-weight” percentage—namely, the percentage of the largest pieces of slate to the total weight of the sample previous to its last division or quartering. The weights of pieces of slate and coal of various sizes (4-inch bar screen to 80-mesh sieve) were determined, and are given in a table and in curve diagrams. A series of experiments with a semi-bituminous coal containing about 5 per cent. of ash in the form of slate and other impurities, in addition to the ash of the coal itself, showed that if a maximum error of 2 per cent. is not to be exceeded, and the probable error is to be less than 0.4 per cent., the “size-weight” percentage must be less than 0.1, whilst it must be as low as 0.01 per cent. if the maximum error is not to exceed 1 per cent., with a probable error of nearly 0.2 per cent.

N. W. Lord,§ in discussing the composition of coal, deals with the analytical methods at present in use, and the importance and difficulties of sampling.

C. Benda|| discusses the most effective methods of taking average samples of coal for analysis.

**Coal Analyses.**—M. Holliger¶ gives the conclusions arrived at from a comparative study of the methods in general use for the determination of sulphur in coal and coke.

M. Dennstedt\*\* deals with the determination of sulphur in coals and

\* *Journal of Industrial and Engineering Chemistry*, July 1909; *Iron Age*, vol. lxxxiv. pp. 392-393.

† *Journal of the American Chemical Society*, vol. xxx. p. 764.

‡ *Journal of Industrial and Engineering Chemistry*, vol. i. pp. 161-178.

§ Address delivered before the Illinois Fuel Conference, March 11, 1909; *Mines and Minerals*, vol. xxx. pp. 85-87.

|| *Eisen Zeitung*, vol. xxx. pp. 321-322, 343-344.

¶ *Zeitschrift für angewandte Chemie*, vol. xxii. pp. 436-449, 492-497.

\*\* *Ibid.*, pp. 677-678.

cokes in reply to M. Holliger's criticisms, and upholds the accuracy of his own process.

N. W. Lord \* deals with the question of coal analysis, and discusses the values of the various methods used in analysing.

D. White, † in his report on the effect of oxygen in coal, gives ultimate analyses of 319 kinds of American coals from the chemical laboratory of the United States Geological Survey.

K. Leo ‡ describes a colorimetric method for the determination of pitch in coal briquettes.

**Determination of Ash in Coke.**—H. E. Hooper § found, when conducting some tests on coke-ovens, that the ratio of the ash in the coke produced did not correspond with that in the coal charged into the ovens. He has, therefore, devised a fresh method for the estimation of the ash, which is described.

#### IV.—ANALYSIS OF GAS.

**Methods of Gas Analysis.**—W. B. Moorhouse || gives an outline and comparison of two methods for determining the amount of sulphur in illuminating gas.

F. B. Shields ¶ details various formulas for computing the results of gas analysis.

G. von Knorre \*\* describes a modification of Jäger's method of analysis of coal gas and similar gaseous mixtures, with special reference to the determination of nitrogen.

**Analysis of Flue Gas.**—The practice of analysing flue gases as a part of the regular routine in conducting boiler tests has been the rule with engineers for some time, and is prescribed in the code of the American Society of Mechanical Engineers for conducting such tests. †† In this code the determination of carbon dioxide, carbon monoxide, and oxygen is provided for, and the benefit that comes from such determinations in all boiler tests is unquestioned; but the committee has endeavoured to determine what value, for the purpose of develop-

\* Paper read at the Illinois Fuel Conference, March 11-13, 1909; *Power*, vol. xxx. pp. 673-676.

† *United States Geological Survey, Bulletin No. 382*, pp. 9-19.

‡ *Chemiker Zeitung*, vol. xxxiii. pp. 359-360.

§ *Engineering and Mining Journal*, vol. lxxxvii. p. 899.

|| *Progressive Age*, vol. xxvii. p. 500.

¶ *Power*, vol. xxx. p. 1121.

\*\* *Chemiker Zeitung*, vol. xxxiii. pp. 717-719.

†† Report of Committee on Power Generation to the Annual Meeting of the American Street and Interurban Railway Engineering Association, October 4, 1909; *Engineering News*, vol. lxii. p. 440.

ing and maintaining higher boiler efficiency, there may be in the practice of making either intermittent quantitative analyses of flue gases by the Orsat apparatus, or continuous analyses with the  $\text{CO}_2$  recorder. The efforts of engineers to make flue-gas analyses have caused many investigations of the actual conditions existing in boiler rooms, which have resulted in a correction of many defects in boiler and furnace settings.

## STATISTICS.

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## I.—UNITED KINGDOM.

**Mineral Statistics.**—According to the official statistics\* the British production of iron ore in 1908 amounted to 15,031,025 tons as against 15,731,604 tons in 1907. The imports of iron ore during the year amounted to 6,057,510 tons, of which over 73 per cent. came from Spain.

The output of coal in 1908 amounted to 261,528,795 tons. The consumption of coal in the United Kingdom was 176,222,659 tons, or 3·956 tons per head of population. The quantity of coal exported, exclusive of coke, patent fuel, and coal shipped for use of steamers engaged in foreign trade was 62,547,175 tons, a decrease of 1,053,772 tons compared with the preceding year. With the addition of patent fuel, coke, and coal shipped for use of steamers engaged in foreign trade, the total amount of coal which left the country was 85,306,136 tons.

The total number of persons employed at mines and at the quarries under the Quarries Act in the United Kingdom and the Isle of Man during the year 1908 was 1,103,215, of whom 1,017,740 were employed in or about mines, and 85,475 in or about quarries. Compared with the preceding year there was an increase of 37,290 males

\* *Mines and Quarries; General Report and Statistics for 1908*, Part III. (Cd. 4937). Price 1s. 5d.

working under ground, and an increase of 7869 males and 361 females working above ground, making a total increase of 45,520 persons. The increase at coal-mines was 47,135, and at iron-mines 531; but at other mines there was a decrease of 2134 males and 12 females.\*

**Iron Trade Statistics.**—The production of pig iron in 1908 is officially stated † to have been 9,056,851 tons. In its production 22,735,268 tons of iron ore and 18,742,464 tons of coal were used. There were  $321\frac{8}{13}$  furnaces in blast out of 513 in existence.

The number of blast-furnaces built and in blast in the United Kingdom on June 30, 1909, were 510 and 314 respectively. The average number of furnaces in blast for the three preceding quarters of the year was: December quarter, 1908,  $310\frac{5}{12}$ ; March quarter, 1909,  $310\frac{5}{12}$ ; June quarter, 1909,  $309\frac{7}{12}$ . ‡

**Cost of Production of Pig Iron.**—A long account has appeared § of the comparative cost of production of pig iron in Great Britain and America. Reference is made to the investigations of Jeremiah Head and A. P. Head, who estimated the cost of pig iron per ton at Pittsburg at £1, 12s. 5½d., and at Middlesbrough at £2, 12s. 2d. This was at the close of the nineteenth century, but since then the cost of production in Britain has been reduced, while in the United States it has gone up by leaps and bounds. In 1898 it was found to be 39s. per ton, and in 1908 it was 58s. 4½d. This increase is caused by the ore having to be got from greater depths, by wages being higher, and by the increased cost of transit, fuel, limestone, &c. Steel has consequently also increased in cost in spite of all improvements in steel-making plant, and the steel industry in the United States is hampered by heavy capital charges, and by the great distances which divide the iron-ore deposits from the coalfields and the manufacturing plants from the sea-board.

**Coke.**—Official statistics relating to the production of coke and of briquettes for 1908 have been published. || The output of coke in Great Britain during the year amounted to 18,537,468 tons, in the manufacture of which 35,233,523 tons of coal were used. The total number of coke-ovens is given as 26,214. The bulk of the ovens were of the beehive type, of which there were 19,478. There were also 1044 Simon-Carvés ovens, 760 Semet-Solvay ovens, 2198 Coppée ovens, 52 Bauer ovens, 378 Koppers ovens, 876 Otto-Hilgenstock ovens, 294 Simplex ovens, 210 Hüssener ovens, 45 Collins ovens, 32 Mackay-Seymour ovens, 10 Proctor ovens, and 837 ovens of types unspecified. Returns were received from 251 plants, excluding gas-

\* *Mines and Quarries; General Report and Statistics for 1908*, Part II. (Cd. 4877). Price 10d.

† *Ibid.*, Part III. (Cd. 4937). Price 1s. 5d.

‡ *Ryland's Iron Trade Circular* (Supplement), July 24, 1909.

§ *Engineer*, vol. cvii. p. 471.

|| *Mines and Quarries; General Report and Statistics for 1908*, Part III. (Cd. 4937). Price 1s. 5d.

works, at 69 of which by-products were recovered. During the year 1,471,448 tons of coal were used in manufacturing 1,604,649 tons of briquettes.

**Metallurgical Education.**—The equipment of the department of applied science at the University of Sheffield is stated to be the most complete of its kind in existence.\* Included in the equipment are a 2-ton Siemens furnace of the latest type, a 1-ton Bessemer converter, with bottom, side, and surface-blowing fittings, a Kjellin electric furnace, annealing furnaces of the Clinch-Jones and ordinary types, a 700-lb. electro-pneumatic hammer, a 50-ton single lever machine for tensile, transverse, crushing, and tension tests, and an air compressor with a capacity of 2000 cubic feet per minute. The micrographic installation consists of a battery of six 4-inch polishing blocks, motor-driven, and eleven microscopes. The pyrometric installation comprises a central station Le Chatelier pyrometer, which can be connected by means of a switchboard to any of the practical or laboratory furnaces, a Uehling pyrometer, a Paul portable pyrometer, a Siemens copper ball pyrometer, and Seger cones.

## II.—AUSTRALASIA.

**Mineral Statistics of Queensland.**—The production of manganese ore in Queensland during 1908 amounted to 1403 metric tons, and the amount of coal raised was 707,473 metric tons.†

**Mineral Statistics of South Australia.**—The production of iron ore during 1907 amounted to 85,954 metric tons, as against 76,430 metric tons in 1906.‡

**Mineral Statistics of Victoria.**—The output of coal in Victoria during 1908 was 113,462 tons, showing a decrease of 25,122 tons compared with the quantity raised during 1907.§

**Mineral Statistics of Western Australia.**—It is stated || that the production of coal in Western Australia during 1908 amounted to 175,248 tons, showing an increase of 32,875 tons over that of the preceding year, and constituting a record.

**Mineral Statistics of New Zealand.**—The quantity of coal raised in New Zealand during 1908 amounted to 1,890,751 metric tons ¶ as compared with 1,831,009 tons in 1907.

\* *Iron Trade Review*, vol. xlv. pp. 209-210.

† *Mineral Industry*, vol. xvii. p. 981.

‡ *Ibid.*, p. 982.

§ *Annual Report of the Secretary for Mines for the year 1908.* Melbourne.

|| *Report of the Department of Mines*, Perth, 1909.

¶ *Mineral Industry*, vol. xvii. p. 982.

**Mineral Statistics of Tasmania.**—The total production of iron ore during 1908 was 3657 metric tons, and the quantity of coal raised was 62,044 metric tons.\*

### III.—AUSTRIA-HUNGARY.

**Mineral Statistics.**—The amount of iron ore produced in Austria-Hungary in 1908 was 2,632,407 tons, as against 2,540,118 tons in 1907, and the quantity of manganese produced amounted to 16,656 tons.†

The production of coal in Austria-Hungary during the first six months of 1909 amounted to 6,818,446 tons, as compared with 7,006,303 tons in the corresponding period of 1908, and the make of coke was 905,128 tons, as against 946,153 tons. The manufacture of briquettes, however, shows an advance.‡

**Iron Trade Statistics.**—The production of pig iron in Austria-Hungary during 1908 amounted to 1,466,897 tons, showing an increase of 83,373 tons over that of the previous year.§

**Mineral Statistics of Bosnia and Herzegovina.**—The mineral production of Bosnia and Herzegovina|| in 1908 was as follows:—

	Tons.
Iron ore . . . . .	149,887
Chrome ore . . . . .	499
Pyrites . . . . .	10,402
Manganese ore . . . . .	6,900
Brown-coal . . . . .	659,962

**Iron Trade Statistics of Bosnia and Herzegovina.**—The production of iron and steel in 1908 was: ¶—

	Tons.
Pig iron . . . . .	51,652
Castings . . . . .	4,612
Open-hearth steel . . . . .	35,506
Rolled bars . . . . .	27,185

### IV.—BELGIUM.

**Mineral Statistics.**—A list of the coal-mines in operation in Belgium, with their output for 1908, has been published.\*\*

\* *Mineral Industry*, vol. xvii. p. 982.

† *Comité des Forges, Bulletin* No. 2885.

‡ *Colliery Guardian*, vol. xcvi. p. 380.

§ *Comité des Forges, Bulletin* No. 2885.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lvii. pp. 575-578.

¶ *Ibid.*

\*\* *Annales des Mines de Belgique*, vol. xiv. pp. 843-881.



**Iron Trade Statistics.**—The output of pig iron in Belgium for the first half of 1909 shows an increase of 161,000 tons over that of the previous half-year. The following figures are given : \*—

	1909. First Half.	1908. First Half.
	Tons.	Tons.
Forge . . . . .	71,080	75,490
Foundry . . . . .	42,970	41,180
Bessemer and basic . . . .	625,430	461,710
Total . . . . .	739,480	573,300

## V.—BRAZIL.

**Mineral Statistics.**—The production of manganese ore in Brazil during 1907 amounted to 236,778 metric tons, as against 121,331 metric tons in 1906.†

## VI.—CANADA.

**Mineral Statistics.**—J. McLeish † states that the production of chromite in Canada during 1908 amounted to 7225 short tons.

W. F. Robertson § states that the production of coal in British Columbia for the year 1908 amounted to 1,677,849 tons.

**Iron Trade Statistics.**—The production of pig iron in Canada during the first half of 1909 amounted to 349,641 tons, of which 99,639 tons was Bessemer and 165,112 tons basic. In this total are included 2159 tons of charcoal pig iron, the remainder being smelted with coke made from bituminous coal. On June 30, 1909, there were sixteen completed blast-furnaces in Canada, of which ten were in blast and six idle. Of this total twelve were equipped to use coke and four to use charcoal. In addition, one coke furnace was being built at Midland, while the construction of a new furnace will soon begin at Sydney, Nova Scotia.||

\* *Iron and Coal Trades Review*, vol. lxxix. p. 87.

† *Mineral Industry*, vol. xvii. p. 1030.

‡ *Advance Chapter of the Annual Report on the Mineral Production of Canada during 1907-1908.* Ottawa.

§ *Annual Report of the Minister of Mines, British Columbia, 1908.*

|| *Bulletin of the American Iron and Steel Association*, vol. xliii. p. 81.

## VII.—CHILI.

**Mineral Statistics.**—According to A. Russell\* the output of coal in Chili since 1902 is as follows:—

	Tons.
1902 . . . . .	827,000
1903 . . . . .	924,000
1904 . . . . .	835,000
1905 . . . . .	882,000
1906 . . . . .	932,000
1907 . . . . .	832,000

## VIII.—CHINA.

**Mineral Statistics.**—The production of coal in China during 1908 amounted to 11,560,000 metric tons, of which 750,000 tons was lignite, 4,810,000 tons bituminous, and 6,000,000 tons anthracite.†

**Iron Trade Statistics.**—The following information is published ‡ respecting the output of the Hanyang Ironworks. In 1908 two old smelting furnaces, improved, produced 66,409 tons of pig iron, of which 5287 tons were converted into open-hearth steel, 60,505 tons into cast iron, and 617 tons into manganese iron. One old and three new open-hearth furnaces—the latter put into operation in September—produced 22,625 tons of steel.

The output from the P'ing Hsiang coal-mines during 1908 was 402,160 tons, and the amount of coke made was 92,183 tons. Three manganese mines have been opened up, from which the ironworks are supplied.

## IX.—FRANCE.

**Mineral Statistics.**—The production of coal during the first six months of 1909 was 18,208,165 tons, of which the Pas-de-Calais basin produced 9,338,757 tons, and the Nord basin 3,488,673 tons, being increases over the 1908 totals of 410,326 tons and 75,549 tons respectively. The total production of coke was 918,813 tons, or a diminution of 17,989 tons on last year.§

Statistics of the production of coal and coke in northern France during 1907 are given, together with particulars of the number of coal-cutting machines, of the consumption of explosives (40 grammes per ton of coal won), and of the accidents in collieries and their causes.||

\* *Transactions of the Mining Institute of Scotland*, vol. xxxii. pp. 13-66.

† *Mineral Industry*, vol. xvii. p. 159.

‡ *Board of Trade Journal*, vol. lxvi. p. 587.

§ *Comité des Forges, Bulletin* No. 2888.

|| *Glückauf*, vol. xlv. pp. 486-489.

**Iron Trade Statistics.**—The number and distribution of furnaces in blast in France at the date of July 1, 1909, was as follows : \*—

In the district of the east . . . . .	65
"    "    "    north . . . . .	14
"    "    "    centre and south-west . . . . .	26
Total . . . . .	105

**Statistics of Laboratory Work.**—L. Guillet † gives a report on the work of the Conservatoire Nationale des Arts et Métiers, Paris, for the year 1908, and tables showing the number of tests and analyses carried out in the various departments, which are as follows : (1) physics; (2) metals; (3) materials; (4) machines; (5) chemistry. The staff of the laboratory consists of forty-nine persons, of which the more important members are the Director, four Departmental superintendents, and six assistants. The total number of the tests of all descriptions made at the laboratory during the year was 1755. The conditions under which work is carried out at the laboratory on behalf of members of the general public are summarised.

## X.—GERMANY.

**Mineral Statistics.**—It is reported ‡ that the production of manganese ore in Germany and Luxemburg in 1908 was 67,693 tons.

During the first half of 1909 the production of coal in Germany, as compared with the production during the first half of 1908, was as follows :—

	Six Months Ending June 1908.	Six Months Ending June 1909.
Coal . . . . .	67,219,263	68,000,175
Lignite . . . . .	26,806,707	26,855,059

The number of mines worked was 267, or one less than at the same time last year. The workmen employed have increased by over 28,000. In the lignite industry 355 mines have been in operation as compared with 373 last year.§

According to the report of the Association of the Rhenish brown-coal industry,|| the total production of brown coal in the Bonn mining district in 1908 was 12,611,000 tons.

\* *Echo des Mines*, vol. xxxvi. pp. 722-723.

† *Revue de Métallurgie, Mémoires*, vol. vi. pp. 1004-1012.

‡ *Glückauf*, vol. xlv. pp. 489-491.

§ *Colliery Guardian*, vol. xcvi. p. 686.

|| *Glückauf*, vol. xlv. pp. 1264-1269.

**Iron Trade Statistics.**—The pig-iron production in Germany and Luxemburg during the first half of the current year, compared with the corresponding period in 1908, has been as follows: \*—

	Six Months Ending June 1908.	Six Months Ending June 1909.
	Tons.	Tons.
Foundry . . . . .	1,222,890	1,163,469
Bessemer . . . . .	211,533	201,027
Basic . . . . .	3,863,830	4,013,133
Ferro and spiegel, &c. . . . .	501,962	£23,350
Forge . . . . .	349,506	351,520
Total . . . . .	6,049,721	6,252,489

According to the official return just issued, the production of pig iron in Luxemburg during 1908 only reached a total of 168,020 tons, as contrasted with 177,160 tons in 1907.†

F. Wüst,‡ in an address at the Königliche Technische Hochschule in Aix-la-Chapelle, reviews the development of the German iron industry in recent years.

**Accidents in Mines.**—According to the Prussian official quarterly journal,§ 1708 fatal accidents occurred in Prussian mines during 1908, 503 men being killed by falls of roof and stone, 140 in shaft accidents, 204 in shaft or haulage inclines, 80 in haulage roads, 378 by explosions, 23 by foul air, 52 in shot firing, 13 by inrushes of water, and 3 by machinery. There were 13 firedamp explosions, killing 8 men and injuring 28; and 2 coal-dust explosions, in which 3 men were injured. The same journal gives a list of all the fire-damp explosions that have occurred from 1861 to 1908 inclusive.

The quarterly official Prussian mining journal|| gives particulars of 26 fatal accidents caused by electricity in German mines during 1908.

Statistics published by the Dortmund Mining Bureau show that at the collieries in that district 336,061 workmen were employed in 1908, and the number of fatalities due to accidents was 1096, or 3·261 per 1000.¶

Tabular statistics of the accidents in collieries in the Breslau mining district, and their causes, are given.\*\*

\* *Iron and Coal Trades Review*, vol. lxxix. p. 91.

† *Colliery Guardian*, vol. xcvi. p. 422.

‡ *Metallurgie*, vol. vi. pp. 265-295.

§ *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. lvii. (Statistics), pp. 47-84.

|| *Ibid.*, pp. 160-173.

¶ *Glückauf*, vol. xlv. pp. 937-941.

\*\* *Ibid.*, p. 530.

## XI.—HOLLAND.

**Mineral Statistics.**—R. C. Mitchell \* reports that the production of coal at the Netherlands State mines in Limburg, which were opened about two years ago, amounted in 1908 to 78,693 tons. The coal produced is of medium quality, being inferior to English and German coal.

## XII.—INDIA.

**Mineral Statistics.**—Sir T. H. Holland † gives the following figures, showing the mineral production of India during 1908 :—

	Tons.
Iron ore . . . . .	59,224
Magnesite . . . . .	7,534
Manganese ore . . . . .	674,315

The production of coal in India in 1908 amounted to 12,769,635 tons, as against 11,147,339 tons in 1907. Of this quantity 97 per cent. was raised in the Bengal coalfield.

## XIII.—ITALY.

**Mineral Statistics.**—The production of minerals in Italy during 1908 included the following: Iron ore, 539,120 tons; manganimiferous iron ore, 17,812 tons; and manganese ore, 2750 tons. ‡

**Iron Trade Statistics.**—During the year 1908 the number of works producing pig iron was five, employing eight blast-furnaces, which produced 112,924 tons of pig iron. The details of the iron and steel production are shown in the following figures : §—

*Iron.*

	Tons.
Rolled bars, shapes, &c. . . . .	252,572
Blooms . . . . .	902
Wire rods, nails, &c . . . . .	7,600
Hoops and bands . . . . .	1,400
Tubes . . . . .	3,200

*Steel.*

	Tons.
Rolled bars, shapes, &c. . . . .	240,312
Blooms and ingots . . . . .	80,805
Rails . . . . .	67,710
Wire, rods, nails, &c. . . . .	15,760
Hoops and bands . . . . .	14,468
Castings for marine and railway works . . . . .	12,316
Springs . . . . .	1,780
Various . . . . .	4,523

\* *Board of Trade Journal*, vol. lxvi. p. 481.

† *Records of the Geological Survey of India*, vol. xxxviii. pp. 71-125.

‡ *Rivista del Servizio Minerario; Iron and Coal Trades Review*, vol. lxxix. p. 821.

§ *Ibid.*

## XIV.—JAPAN.

**Mineral Statistics.**—The output of Japanese collieries in 1908 amounted to 14,468,664 tons, this being an increase of about  $3\frac{1}{2}$  per cent. on the 1907 total.\*

**Iron Trade Statistics.**—According to official statistics of the Imperial Japanese Government, the production of pig iron in Japan in 1908 was 13,851,473 kwan, which amounts to about 51,943 metric tons.†

## XV.—RUSSIA.

**Mineral Statistics.**—The output of manganese ore in the Caucasus during 1908 showed a marked decline as compared with the previous year, the figures being respectively 112,180 tons and 658,600 tons. This reduction of the output resulted from a great number of the mines being shut down.‡

The total quantity of chrome iron ore produced in the southern Urals in 1908 was 36,805 poods.§

## XVI.—SWEDEN.

**Mineral Statistics.**—According to official statistics, the production of iron ore in Sweden in 1908 was 4,713,160 metric tons, and the output of coal in 1908 was 305,206 metric tons.

H. Sundholm|| estimates that since the thirteenth century there has been mined in Sweden about 113,000,000 tons of iron ore, of which about 70 per cent. has been used within the country, and about 30 per cent. exported. At the present time about 4,600,000 tons are mined annually.

**Iron Trade Statistics.**—According to an advanced summary of the official statistics kindly communicated by R. Åkerman, Honorary Member, the production of pig iron and manufactured iron and steel in Sweden in 1908 was as follows:—

	Metric Tons.
Pig iron . . . . .	567,821
Charcoal blooms from pig iron . . . . .	152,256
Bessemer ingots and castings . . . . .	81,054
Open-hearth ingots and castings . . . . .	355,394
Crucible ingots and castings . . . . .	1,169
Blister steel . . . . .	510
Bar iron and steel . . . . .	181,433
Nails, wire rods, and bands . . . . .	116,860
Other shaped iron and steel in bars . . . . .	25,006
Plates (not including sheets) . . . . .	20,598
Tube-blocks and hollow blooms . . . . .	44,517

\* *Colliery Guardian*, vol. xcvi. p. 485.

† *Eisen Zeitung*, vol. xxx. p. 877.

‡ *Iron and Coal Trades Review*, vol. lxxix. p. 125.

§ *Mining Journal*, vol. lxxxv. p. 525.

|| *Teknisk Tidskrift (Afdelningen för Kemi och Bergsvetenskap)*, vol. xxxix. pp. 81–82.

The number of blast-furnaces in blast was 121, and the average daily production per furnace was 17.95 metric tons. The average time that each furnace was in blast was 261 days.

The production of iron and steel during the first half of 1909 was as follows: \*—

	Tons.
Pig iron . . . . .	285,900
Puddled iron . . . . .	61,200
Bessemer ingots . . . . .	40,900
Open-hearth ingots . . . . .	158,100

**Consumption of Wood and Charcoal.**—Statistics are given † of the consumption of wood and charcoal in Sweden during the period 1896–1907. The average annual consumption of charcoal for the iron industry has been 4,562,984 cubic metres, and the total average annual consumption of wood is estimated at 34,822,358 cubic metres.

## XVII.—UNITED STATES.

**Mineral Statistics.**—The production of manganese ores in the United States during 1908 amounted to 6144 gross tons as compared with 5604 tons in 1907, and 6921 tons in 1906. ‡

The total production of chrome iron ore in the United States in 1908 was 359 gross tons.§

The total production of coal in the United States during 1908, as reported to the United States Geological Survey, was 415,842,698 net tons, of which 74,347,102 gross tons were Pennsylvania anthracite, and 332,573,944 net tons were bituminous and lignite.||

**Bauxite.**—According to statistics of the United States Geological Survey, the total production of bauxite in 1908 amounted to 52,167 tons, as against 97,776 tons in 1907. Arkansas and Georgia were large contributors to the output.¶

The production of other minerals in the United States in 1908 was: \*\*—

Graphite (crystalline) . . . . .	3,433,039 lbs.
Limestone flux . . . . .	9,650,000 tons.
Magnesite . . . . .	8,967 tons.
Petroleum . . . . .	184,711,413 barrels.

**The Iron-ore Resources of the United States.**—C. W. Hayes †† gives an abstract of a report, prepared for the Conservation Commission of the United States, on the subject of the iron-ore supply. The ores are grouped into four main classes: (1) magnetite ores; (2)

\* *Iron and Coal Trades Review*, vol. lxxix. p. 665.

† *Bihang till Jernkontorets Annaler*, 1900, pp. 396–408.

‡ *Bulletin of the American Iron and Steel Association*, vol. xliii. p. 81.

§ *Annual Report of the United States Geological Survey; Iron and Coal Trades Review*, vol. lxxix. p. 238.

|| *Bulletin of the American Iron and Steel Association*, vol. xliii. p. 89.

¶ *Engineering and Mining Journal*, vol. lxxxviii. p. 76.

\*\* *Ibid.*, vol. lxxxvii. p. 1095.

†† *United States Geological Survey, Bulletin No. 394*, pp. 70–113.

hæmatite ores; (3) brown ores; and (4) carbonate ores; and into six districts, namely—

I. North-Eastern—Vermont, including Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, and Ohio.

II. South-Eastern—Virginia, West Virginia, Eastern Kentucky, North Carolina, South Carolina, Georgia, Alabama, and East Tennessee.

III. Lake Superior—Michigan, Minnesota, and Wisconsin.

IV. Mississippi Valley—North-West Alabama, West Tennessee, West Kentucky, Iowa, Missouri, Arkansas, and East Texas.

V. Rocky Mountain—Montana, Idaho, Wyoming, Colorado, Utah, Nevada, New Mexico, West Texas, and Arizona.

VI. Pacific Slope—Washington, Oregon, and California.

In the table given on the next page the available ores are indicated in the columns marked A, while those in the columns marked B cannot be considered as available for iron-making purposes.

Estimates of the foreign ore supplies in British Columbia, the Canadian portion of the Lake Superior district, Nova Scotia, Newfoundland, Mexico, and Cuba give 1,578,000,000 tons of ore available. With the present rate of consumption of ores in the United States, it is estimated that by 1940 the production must have reached a maximum and begun to decline, as with the present annual increase the production could not continue even for thirty years.

According to J. G. Butler, jun.,\* the total amount of iron ore available in the United States is 4,462,940,000 tons, made up as follows:—

	Tons.
Lake Superior . . . . .	1,618,000,000
New York . . . . .	750,000,000
New Jersey . . . . .	135,000,000
Pennsylvania . . . . .	45,000,000
South . . . . .	1,814,940,000
Rocky Mountain district . . . . .	100,000,000
Total . . . . .	4,462,940,000

**The Coal Resources of the United States.**—M. R. Campbell† and E. W. Parker discuss the coal resources of the United States. The estimated area of workable coal-beds is 496,776 square miles, divided into anthracite, bituminous, and semi-bituminous beds, and the fields are, for convenience of classification, divided into six main provinces: (1) the Eastern province; (2) the Interior province; (3) the Gulf province; (4) the Northern, or Great Plains province; (5) the Rocky Mountain province; and (6) the Pacific Coast province. The Geological Survey estimates of the quantity of coal contained within the known area of the United States, when mining was first commenced, were 3,076,204,000,000 tons, of which a little less than two-thirds, or 1,922,979,000,000 tons was considered to be coal easily accessible, and 1,153,225,000,000 tons as coal only accessible with great difficulty. This estimate includes, however, the lignites and

\* *Iron Trade Review*, xlv. p. 14.

† *Bulletin of the American Institute of Mining Engineers*, 1909, pp. 365–372.



*Estimated Reserve of Iron Ore in the United States.*

District.	Magnetite Ores.				Hematite Ores.				Brown Ores.		Carbonate Ores.		Total Supplies.	
	Non-Titaniferous.		Titaniferous.		Specular and Red.		Clinton.		A.	B.	A.	B.	A.	B.
	A.	B.	A.	B.	A.	B.	A.	B.						
I.	Tons. 160,000,000	Tons. 111,500,000	Tons. 90,000,000	Tons. 100,000,000	Tons. 2,000,000	Tons. 2,000,000	Tons. 35,000,000	Tons. 620,000,000	Tons. 11,000,000	Tons. 13,500,000	Tons. ..	Tons. 248,000,000	Tons. 298,000,000	Tons. 1,085,000,000
II.	12,500,000	23,000,000	..	..	8,000,000	58,000,000	403,000,000	970,500,000	54,400,000	168,000,000	..	62,000,000	538,440,000	1,276,500,000
III.	..	4,500,000,000	..	25,000,000	3,500,000,000	67,475,000,000	10,000,030	30,000,000	..	..	..	..	3,510,000,000	72,080,000,000
IV.	..	..	..	..	15,000,000	10,000,000	..	..	300,000,000	560,000,000	..	..	315,000,000	570,000,000
V.	51,485,000	115,440,000	..	1,500,000	4,275,000	21,00,000	..	..	2,000,000	1,625,000	..	..	57,760,000	120,665,000
VI.	68,950,000	11,900,000	..	2,000,000	..	10,000,000	..	..	..	106,000	..	..	68,960,000	28,905,000
Totals	292,935,000	4,761,740,000	90,000,000	128,500,000	3,520,275,000	67,552,100,000	508,540,000	1,620,500,000	367,400,000	743,280,000	..	310,000,000	4,788,150,000	75,114,070,000

sub-bituminous coals of the Western States, of which 530,000,000,000 tons, while easily accessible, cannot be considered as available under present conditions, or those likely to occur in the near future. This reduces the original supply of easily accessible and available coal to 1,392,979,000,000 tons. Up to the end of 1907, 6,865,097,567 tons of coal may be estimated to have been mined, and as for every ton of coal mined and sold half a ton is lost or wasted, the total production, in short tons, to the end of 1907 may be estimated to have been 10,200,000,000 tons, or 0.3 per cent. of the original available supply, and 0.7 per cent. of the coal easily accessible and available under present conditions. The total reserve of such coal is now estimated at 1,382,780,000,000 tons, and the assumption that a constant output has now been reached would be unwarrantable. On the other hand, the adoption of the present direct rate of increase, which is 7.36 per cent. per annum, would involve the improbable assumption that the marvellous record of past and present progress will be maintained in the future, and that the production will continue approximately to double every decade. Using the waste allowance, on the basis of this constant rate of increase, the supply available at the close of 1907, 1,382,780,000,000 tons, would be exhausted in 107 years, or by the year 2015; and it is pointed out that the figures set fifty years ago by statisticians in Great Britain for the probable constant annual production in Great Britain have already been exceeded by 160 per cent. On the other hand, as the rate of increase of the population tends to diminish, the direct rate of increase in the production of coal may also diminish, and a constant annual production may ultimately be reached, while the increased use of water power should exercise a similar effect.

**Peat Resources of the United States.**—C. A. Davis \* estimates that at a rough approximation the peat beds of the United States, exclusive of those of Alaska, would yield 12,888,000,000 tons of dry fuel. The use of peat is at present almost unknown in that country.

**Iron Trade Statistics.**—According to statistics collected by J. M. Swank, † the total production of pig iron in the United States for the first half of 1909 amounted to 11,022,346 tons. Compared with the production for the corresponding period in 1908 it shows an increase of 4,104,342 tons. Of the above total 4,481,490 tons were Bessemer and low phosphorus, 3,288,573 tons basic, 171,389 tons charcoal, 80,785 tons spiegeleisen and ferro-manganese, and 3,000,109 tons other kinds of pig iron.

According to statistics collected by the American Iron and Steel Association, the production in 1908 of crucible steel ingots amounted to 55,360 tons, and of crucible steel castings 8271 tons. The production of structural shapes amounted to 1,083,181 tons, and of iron and steel wire rods to 1,816,949 tons. ‡

\* *United States Geological Survey, Bulletin No. 394*, pp. 62-69.

† *Bulletin of the American Iron and Steel Association* (Supplement), July 1909.

‡ *Iron Age*, vol. lxxxiii. pp. 1358-1359.

**Laboratories in the United States.**—An illustrated description by L. D. Huntoon\* has appeared of the Hammond Mining and Metallurgical Laboratory of the Sheffield Scientific School, Yale University.

### XVIII.—COMPARATIVE TABLES.

**The World's Production of Coal and Iron.**—For purposes of comparison the following summary of the production of coal in the principal countries of the world is appended:—

Country.	Year.	Production in Tons.
United Kingdom . . . . .	1908	261,528,795
Australasia—		
New South Wales . . . . .	1908	9,147,025
New Zealand . . . . .	1908	1,890,751
Queensland . . . . .	1908	707,473
Tasmania . . . . .	1908	62,049
Victoria . . . . .	1908	113,462
Western Australia . . . . .	1908	175,248
Austria-Hungary, coal . . . . .	1908	14,091,160
" lignite . . . . .	1908	26,669,708
Belgium . . . . .	1908	23,678,159
Bosnia and Herzegovina (brown-coal) . . . . .	1906	659,962
British Borneo . . . . .	1906	62,974
Bulgaria . . . . .	1906	133,205
Canada . . . . .	1908	10,904,466
Cape Colony . . . . .	1907	144,040
Chili . . . . .	1907	832,000
China . . . . .	1908	11,560,000
Corea . . . . .	1906	5,896
Dutch East Indies . . . . .	1906	389,006
France . . . . .	1908	36,770,212
Germany, coal . . . . .	1908	148,621,202
" lignite . . . . .	1908	66,450,144
Greece, lignite . . . . .	1907	11,720
Holland . . . . .	1906	532,780
India . . . . .	1908	12,769,635
Indo-China . . . . .	1906	315,000
Italy, coal and lignite . . . . .	1907	453,137
Japan . . . . .	1908	14,468,684
Mexico . . . . .	1906	700,000
Natal . . . . .	1908	1,669,774
Orange River Colony . . . . .	1907	499,590
Peru . . . . .	1907	185,000
Poland . . . . .	1907	4,523,227
Portugal, anthracite . . . . .	1906	6,762
Rhodesia . . . . .	1906	94,168
Russia . . . . .	1907	24,882,692
Servia . . . . .	1906	272,241
Spain . . . . .	1906	3,095,043
Sumatra . . . . .	1906	277,097
Sweden . . . . .	1908	306,206
Transvaal Colony . . . . .	1907	2,912,083
United States . . . . .	1908	415,842,698
Venezuela . . . . .	1906	14,064

\* *Bulletin of the American Institute of Mining Engineers*, 1909, pp. 229-248.

A similar summary showing the production of pig iron is as follows:—

Country.	Year.	Production in Tons.
United Kingdom . . . . .	1908	9,056,851
Austria-Hungary . . . . .	1908	1,466,897
Belgium . . . . .	1908	1,206,440
Bosnia and Herzegovina . . . . .	1908	51,652
Canada . . . . .	1908	630,835
France . . . . .	1908	3,391,150
Germany and Luxemburg . . . . .	1908	11,813,511
Italy . . . . .	1908	112,924
Japan . . . . .	1908	51,943
Russia . . . . .	1908	2,748,000
Spain . . . . .	1907	390,000
Sweden . . . . .	1908	567,821
United States . . . . .	1908	15,936,018

**World's Coal Resources.**—It is estimated\* that the world's available supply of coal is as follows:—

	Millions of Tons.
Great Britain . . . . .	146,875
United States . . . . .	2,000,000
China . . . . .	1,500,000
New South Wales . . . . .	15,000
Spain . . . . .	4,000
Japan . . . . .	50,000
France . . . . .	25,000
Austria-Hungary . . . . .	30,000
Germany . . . . .	164,344
Belgium . . . . .	20,000
Total . . . . .	3,955,219

**World's Production of Iron.**—B. Neumann† gives comparative statistics of the production of iron ore, pig iron, and steel in the chief iron-producing countries during 1907 and 1908.

**Comparative Production of Steel in Great Britain, Germany, and United States.**—In connection with the thirtieth anniversary of the introduction of the basic process in Germany, the following comparative statistics have been issued:‡—

\* *Moniteur Industriel*, No. 321, May 22, 1909, p. 330.

† *Glückauf*, vol. xlv. pp. 1179-1185, 1216-1221.

‡ *Stahl und Eisen*, vol. xxix. pp. 1488.

*Production of Steel in Great Britain.*

Year.	Acid Process.		Basic Process.	
	Open-hearth.	Bessemer.	Open-hearth.	Bessemer.
	Tons.	Tons.	Tons.	Tons.
1900	2,908,367	1,273,967	296,180	498,857
1901	2,993,760	1,133,841	359,795	498,112
1902	2,719,332	1,175,695	413,288	679,296
1903	2,655,086	1,336,986	518,982	602,592
1904	2,624,615	1,147,292	672,657	662,746
1905	3,091,519	1,418,573	807,961	587,224
1906	3,432,750	1,328,063	1,195,065	609,792
1907	3,438,937	1,300,800	1,299,168	588,207
1908	2,620,102	920,970	1,258,075	581,226

*Production of Steel in Germany.*

Year.	Acid Process.		Basic Process.	
	Bessemer.	Open-hearth.	Bessemer.	Open-hearth.
	Tons.	Tons.	Tons.	Tons.
1894	327,700	161,100	2,342,161	899,111
1895	315,600	158,000	2,520,396	1,018,807
1896	351,600	184,100	3,004,615	1,292,832
1897	...	...	3,234,214	1,304,423
1898	...	...	3,606,737	1,459,159
1899	...	...	3,973,225	1,693,825
1900	223,063	147,800	4,141,587	1,997,765
1901	299,816	125,590	3,975,070	1,886,536
1902	341,885	129,724	4,888,054	2,304,495
1903	435,327	132,693	5,473,195	2,628,544
1904	423,742	130,546	6,525,429	2,697,760
1905	424,196	165,930	6,203,706	3,086,590
1906	407,688	230,668	6,772,804	3,534,612
1907	387,120	212,620	7,212,454	4,039,240
1908	374,100	146,768	6,510,754	3,854,155

*Production of Steel in the United States.*

Year.	Acid Process.		Basic Process.
	Open-hearth.	Bessemer.	Open-hearth.
	Tons.	Tons.	Tons.
1900 . . . . .	866,693	6,791,726	2,585,812
1901 . . . . .	1,053,913	8,852,715	3,676,897
1902 . . . . .	1,210,255	9,284,577	4,568,478
1903 . . . . .	1,113,410	8,730,314	4,817,784
1904 . . . . .	814,120	7,984,886	5,188,069
1905 . . . . .	1,174,186	11,116,437	7,940,777
1906 . . . . .	1,342,799	12,473,243	9,813,306
1907 . . . . .	1,290,090	11,854,230	10,443,783
1908 . . . . .	707,445	6,214,623	7,197,921

**World's Production of Chromite.**—J. McLeish \* states that the world's production of chromite in 1907 was probably between 90,000 and 100,000 metric tons. Turkey has been a large producer of this mineral, but only incomplete records of exports are available. A table is given showing the available records of chromite supplies from 1903 to 1908.

**World's Production of Nickel.**—The world's production of nickel during 1908 is estimated at 12,800 metric tons, as compared with 14,100 metric tons in 1907.†

**World's Production of Tungsten.**—J. L. Walker,‡ in his report on the tungsten ores of Canada, gives a table showing the world's production during 1905 and 1906.

\* *Advance Chapter of the Annual Report on the Mineral Production of Canada during 1907-1908.* Ottawa.

† *Iron and Coal Trades Review*, vol. lxxix. p. 383.

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